EXPOSITION ISSUE

NOVEMBER 1951

Your Chemical Show Guide Pages 33 to 69

Chemical Engineering Progress

PUBLISHED MONTHLY BY THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

Inert Reaction Media
WITH PLUS BENEFITS
Diethyl "CARBITOL"
Dibutyl "CELLOSOLVE"
Dibutyl "CARBITOL"
Dibutoxy Tetraglycol
These high-purity ethers offer the following advantages as reaction media:
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+ convenient handling
+ reduced solvent loss
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+ reduced fire hazard
ALL FOUR ARE AVAILABLE IN COMMERCIAL QUANTITIES

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Try these glycol di-ethers and select the one that best meets your needs. Call or write our nearest office today for samples and additional information.

Formula	Specific Gravity 20/20° C.	Boiling Point at 760 mm. Hg °C.	Solubility at 20° C. (% by weight) in water	water in	Flash Point °F.
Diethyl CARBITOL $C_2H_5O(C_2H_4O)_2C_2H_5$	0.9082	188.9	Complete	Complete	155
Dibutyl CELLOSOLVE $C_4H_9OC_2H_4OC_4H_9$	0.8374	203.3	0.2	0.6	185
Dibutyl CARBITOL $C_4H_9O(C_2H_4O)_2C_4H_9$	0.8853	254.6	0.3	1.4	260
Dibutoxy Tetraglycol $C_4H_9O(C_2H_4O)_4C_4H_9$	0.9436	330.0	1.3	4.8	355

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Number 11

Chemical Engineering Progress

NOVEMBER
1951

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WALK THE BOARDWALK IN ATLANTIC CITY, DECEMBER 2-5, 1951

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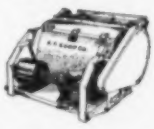

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362 and 364

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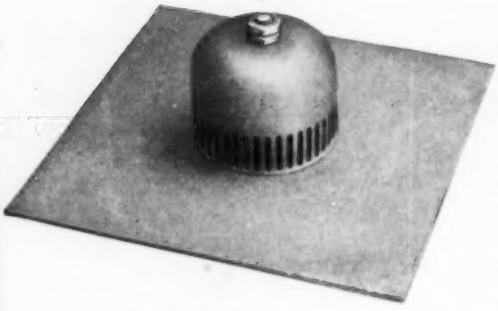

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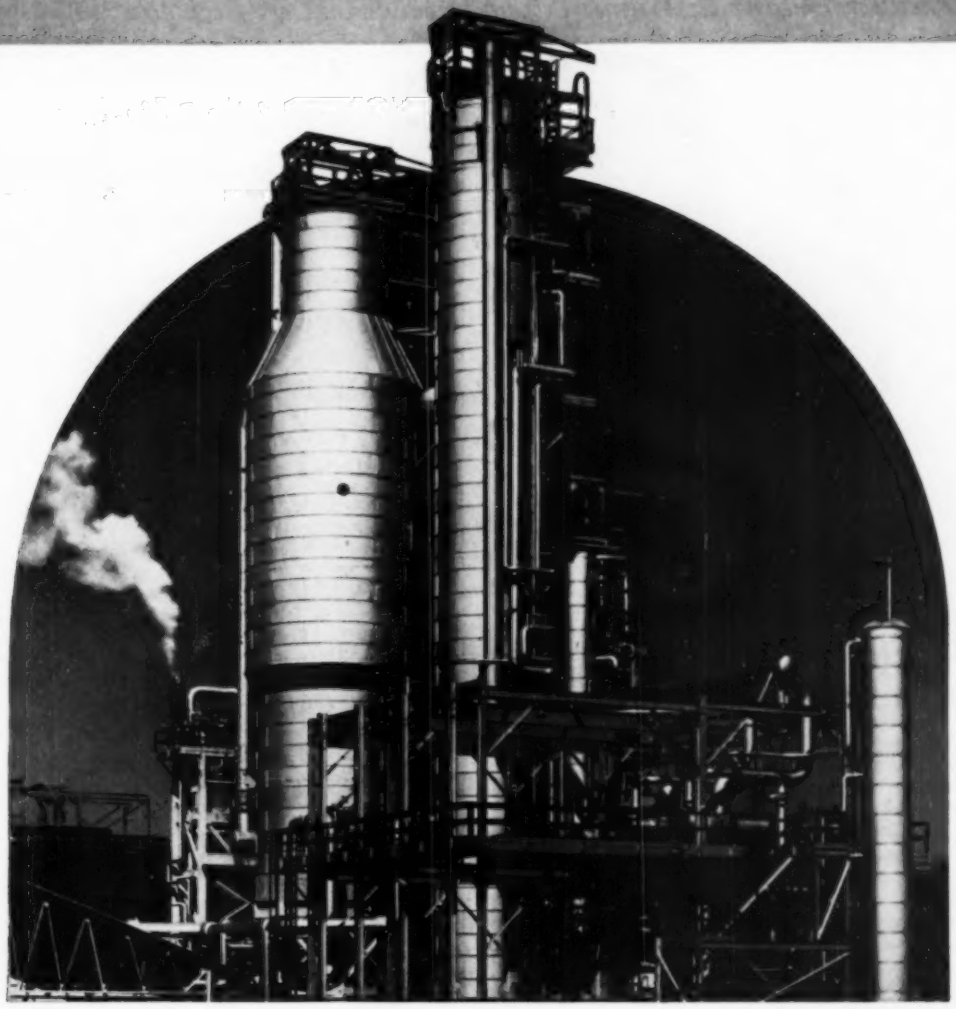

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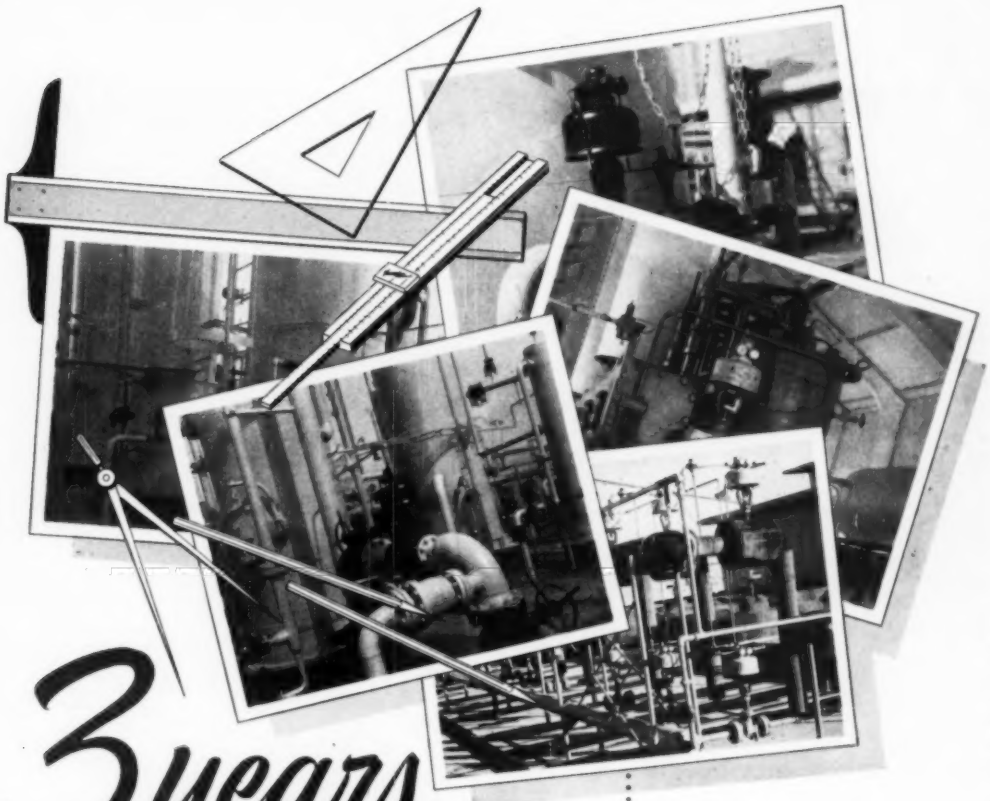

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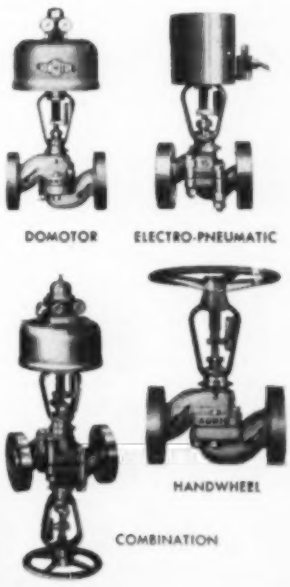

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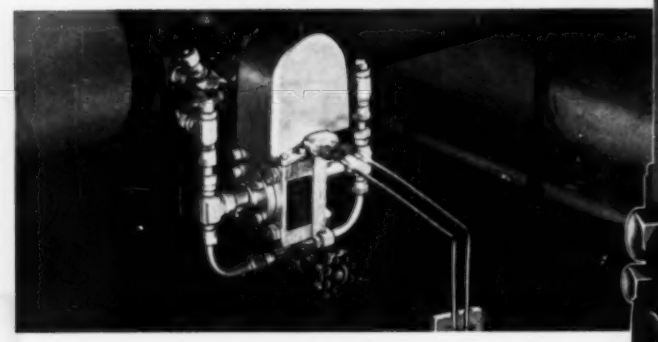

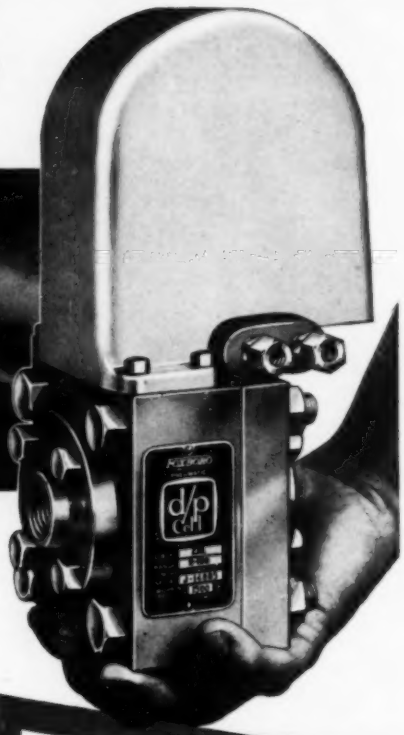

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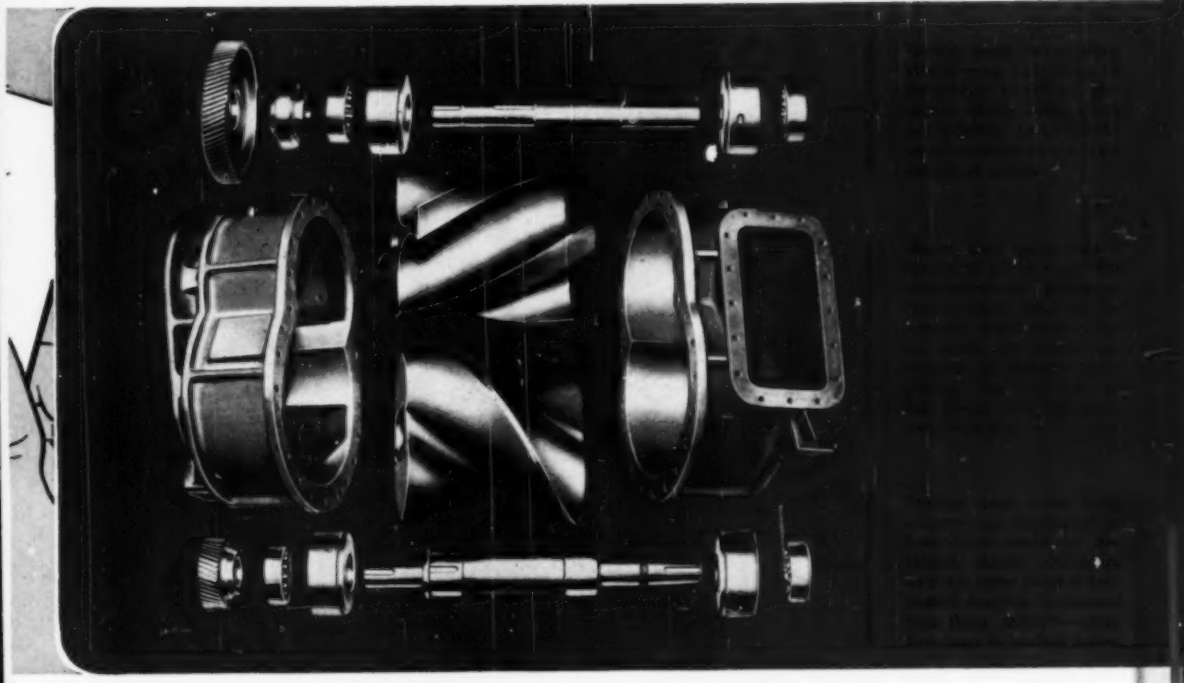
STANDARDAIRE—IT'S BUILT TO "TAKE IT"— Rarely does a manufacturer have an opportunity to measure the efficiency and quality of his product after a period of continuous trouble-free service. In a recent instance, however, Read Standard had such an opportunity and now releases the performance data on Standardaire Blower 9B16-213. This blower operated in a large Chemical Plant for a period of fifteen (15) months—24 hours a day—at a speed of 2200 rpm—pressure 12 psig—air delivery 1950 cfm. During fifteen (15) months of operation it is calculated that the Standardaire Blower handled 1⅓ BILLION cubic feet of high pressure air and made approximately 1½ BILLION revolutions—equivalent to over 20 years service for the average lobe type blower (40 hours per week at 500 rpm). The need for a still greater volume of air in their system prompted the chemical company to install a larger Standardaire Blower. The used blower was then sealed and returned to the factory for inspection.

STANDARDAIRE—INSPECTION AFTER 15 MONTHS SERVICE: Even after the hard and difficult service this blower performed it was found to be in excellent condition when dismantled and inspected in the presence of the chemical company's representative. No oil leaks had developed and the internal parts were completely dry and free of oil. Pump circulated oil was used for lubrication. The main and gate rotors were in perfect shape and showed no indication of wear. Neither was there any evidence that the rotors had made contact with each other or with the housing. Combination thrust radial bearing on the main rotor shaft carried the heaviest load due to thrust created by the main rotor. The actual clearance in this bearing was checked with a dial

# of performance in 15 months Service



LONG LIFE----
have STAYING POWER

indicator and it was found that it had increased less than .0005". The other anti-friction bearings were found to be in perfect condition. Gear wear was so small that no increase in backlash could be detected. Even at the extremely high peripheral speed of these gears they were found to be very quiet in service.

STANDARDAIRE—FOR THAT EXTRA LIFE: This factual information is presented to acquaint the users of blower equipment with the extra life built into all Standardaire Blowers. Read Standard offers industry a wide range of axial flow, positive displacement blowers. They are modern in design—superior in performance—dependable in operation. For staying power and maximum efficiency it's the Standardaire Blower. For further information write Dept. E-41.

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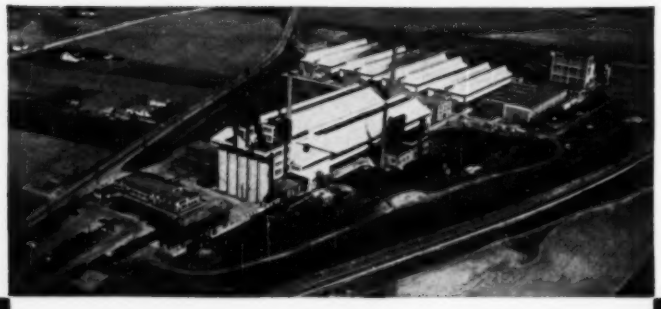

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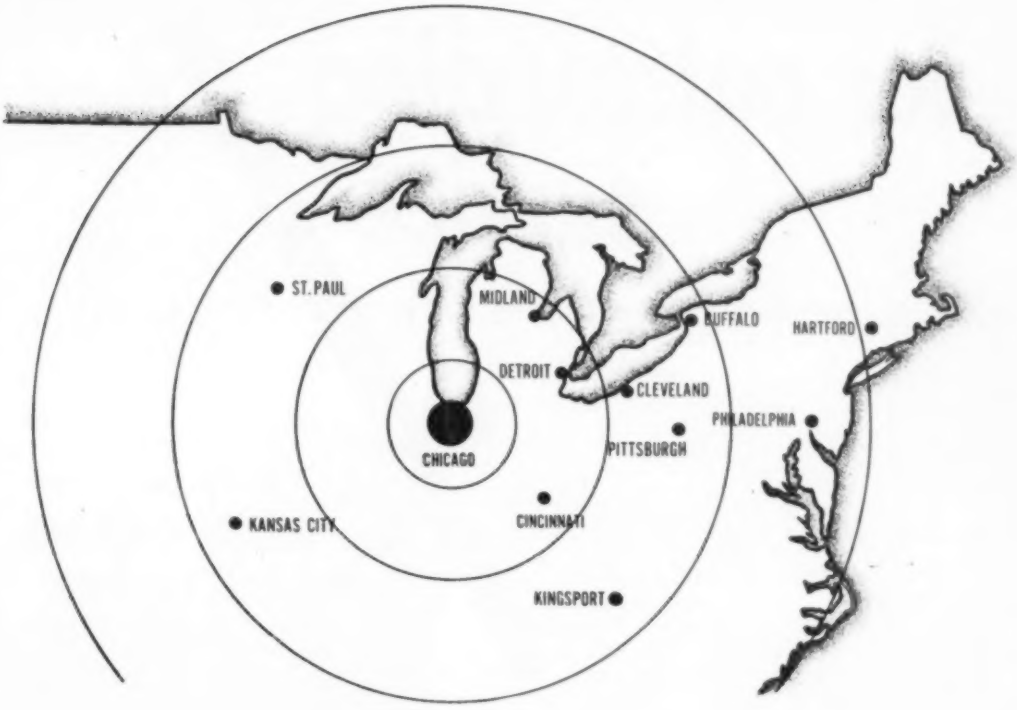

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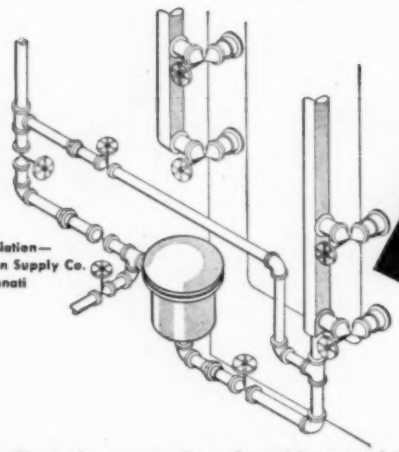

The installation—
American Linen Supply Co.
Cincinnati

PROBLEM: To equip a steam-heated tumbler-type drier with a trap that would reduce start-up time to a minimum, and provide, automatically, a smooth, steady flow of hot, dry steam to the unit, with the lowest possible maintenance cost.

WORKING CONDITIONS: Steam pressure to drier, 125 pounds. Drier operated 16 hours daily on continuous batch basis.

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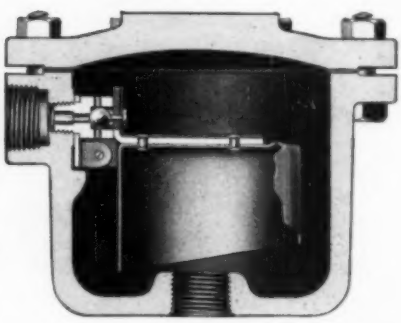

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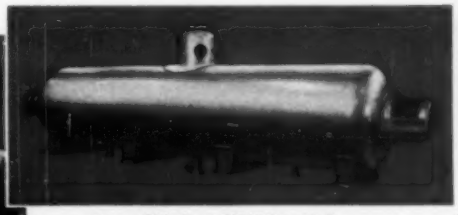

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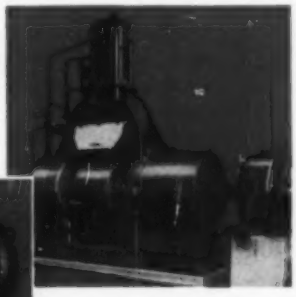

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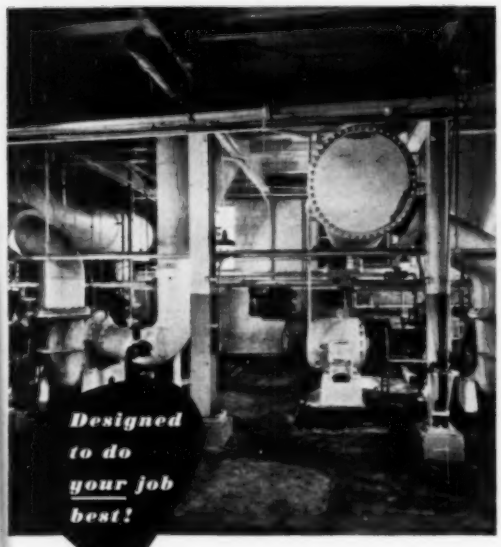

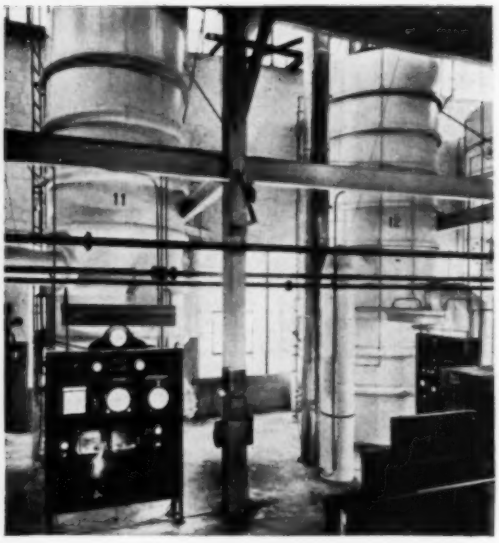

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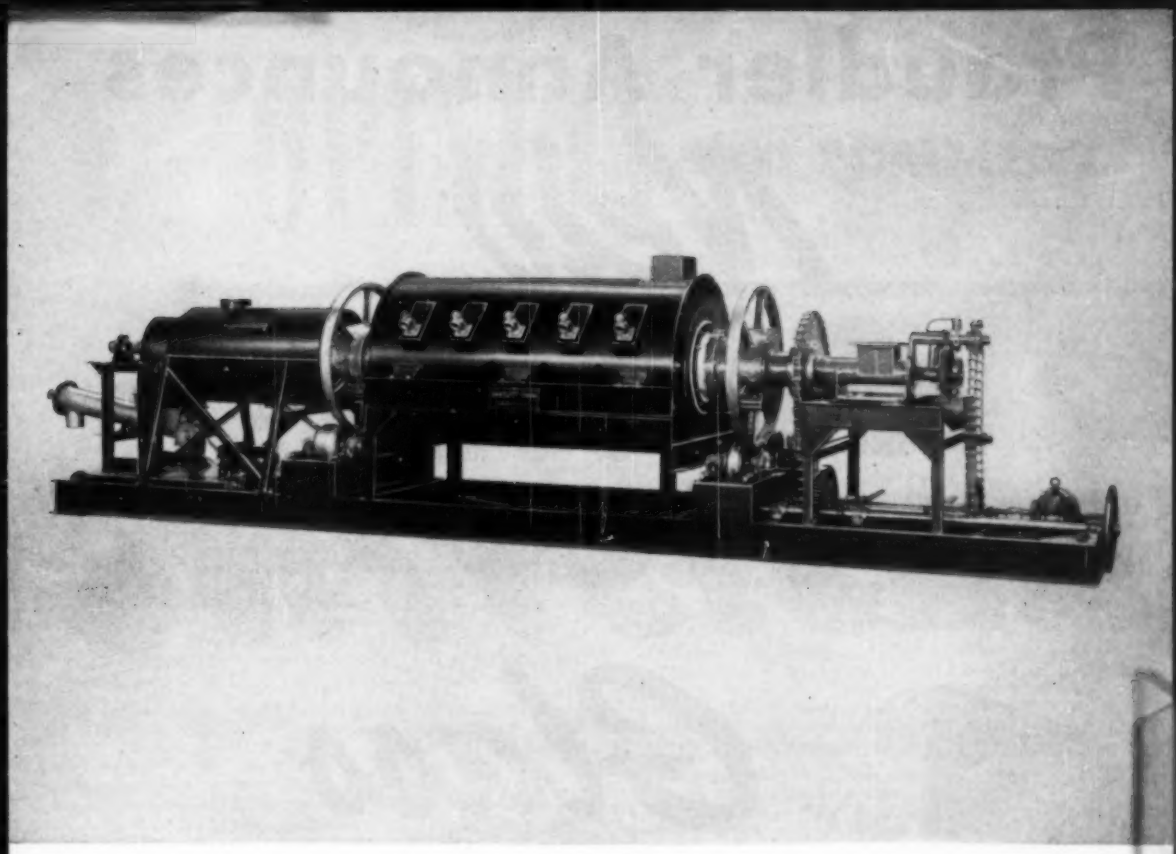

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OPINION AND COMMENT

POST-COLLEGE SLUMP

AN old disease in young engineers is now receiving the attention of the profession's physicians who have tersely labeled the infirmity "post-college slump." This condition, fatal to many, usually strikes during the first five years after graduation from college. It is characterized by a decreased interest in education and educational processes, shunning of professional contacts, a lack of interest in mental growth, a sense of discouragement about the engineering profession, and a high rate of mortality evidenced by the number of graduates leaving the engineering field.

Etiological studies indicate that it is caused by an abrupt change from the scholastic environment to an industrial environment which does not "challenge ability, utilize capacity or give an incentive to plan for the future." Other conditions are suspect also. The young man, prior to industrial life has been devoted to his own individual development, more or less required of him in the close supervision of the classroom. The switch to industry brings him to an environment where interest shifts from himself, to an impersonal company.

At the annual meeting of the Engineers' Council for Professional Development in Boston last month, the problem of post-college slump was discussed for the second time. At its previous annual meeting E.C.P.D. had received from its Committee on Professional Training, a 200-page manual outlining a six-point program for combating professional disinterest during the first five post-graduation years. The chairman of the committee at that time was A. C. Monteith, vice-president and in charge of engineering research of the Westinghouse Electric Corp., and subsequently E.C.P.D. tried to raise $20,000 from various sources to help carry out the suggested development program. As detailed there, the six-point program covered orientation and in-service training; continued college education; introduction to community service; indoctrination in characteristics; responsibilities, and ethics of the profession leading to recognition through registration; self-appraisal for the purpose of orienting personal plans, and selected reading for professional and personal growth. The plan called for a field director to help organize resources and agencies which would help to establish programs along such lines for professional help in whatever communities could best handle them.

From the annual report of Harry S. Rogers, chairman of E.C.P.D., we learn that the $20,000 was not forthcoming. The drive for funds went as high as $14,000, obtained from the professional societies making up E.C.P.D., and the Engineering Foundation. E.C.P.D. hoped to implement the program by contributions, not only from professional societies but also from industry. Industry has an undeniable stake in developing the new (and older) engineers into live personalities, aware not only of the latest technical development, but professional problems as well.

H. P. Hammond, dean emeritus of Pennsylvania State College, described in his contribution to the panel at Boston, the condition and a partial cure. As a matter of fact the quotations at the beginning of this editorial are from his remarks. The Dean proposed two measures, one of continued mental development through organized educational programs and the other, aid to the graduate to acquire professional consciousness.

His message proved that the combined incentiveness of engineering societies and industry can bring to a city, no matter how far removed from a college center, the best in graduate engineering courses. Dean Hammond cited the case at Pennsylvania State where advanced courses were administered last year at distances 90 miles and 200 miles from the college campus.

Industry has many tasks thrust upon it by those peddling panaceas, and this editorial is not a recommendation that industry underwrite completely the E.C.P.D. program. However, if professional societies can raise $14,000 of a needed $20,000 for missionary work aimed at implementing larger efforts, which would in the end benefit industry by making better engineers, the needed $6,000 should easily have been forthcoming.

The kind of program for a particular community can best be left to the local engineering societies and the E.C.P.D. The emphasis may be needed on post-college education, community service, professional licensing, or other areas. These should be determined by all the local engineering societies working together as a unit of E.C.P.D. After the need for a professional development program is determined, financial means for its support can then be found at a local level. Such support may take the form of tuition from the students, contribution from the engineering groups, and subsidy from industry. Even though industry would benefit greatly by any program which produces better engineers, we must not lose sight of the fact that for the individual to receive full value, he must be willing to give heavily of his spare time and energy. That, first, is the necessity, and E.C.P.D. has the opportunity, if given the proper support, of convincing our new men that professional alertness pays. The chemical industry, we must say, has known for some time the value of the extra effort. This magazine has told several times in editorials and in articles of the Humble Lectures in Science. Companies, through the urging of the A.I.Ch.E. Student Chapter Committee, have cooperated in sending, to speak before student chapter meetings, recent graduates who could tell about life as an engineer in industry. Local sections have sponsored lecture series, and student contests. Chemical industry has sent men back to college and brought professors in to work in industry. As a matter of reason, the attendance at meetings of the Institute by men from industry year after year is recognition that professional associations are valuable. Now the E.C.P.D. program offers an opportunity to extend and expand that philosophy and service right into your own back yard.

F. J. VAN ANTWERPEN, *Editor*

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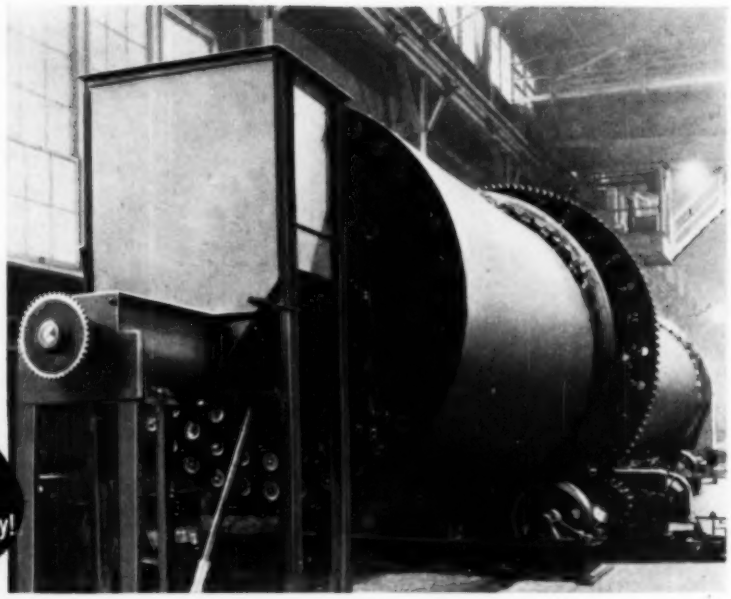

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FABRIC FILTER MEDIA

E. G. SMITH

Equipment Development Company, Inc., Montclair, New Jersey

E. G. SMITH is president of Equipment Development Co., a firm acting as filtration consultants, designers and manufacturers of continuous filtration equipment. Mr. Smith has been engaged in the filtration field for the past 25 years, and has been especially interested in the perfection of continuous vacuum filtration equipment. During the past five years he has given considerable time to the development of fabric filter media of entirely new construction by the use of plastic yarns; these have thrown a different light on the physical performance of filter media and modified certain of the previous concepts of their behavior in general. He is an active member of the New Jersey Section, A.I.Ch.E.

This and the succeeding article in this number conclude the series on filtration started in October issue. . . . In discussing the theory of operation Mr. Smith covers various fabrics and yarns, and Mr. Fuhrmeister adds information gained from practical field experiments showing the physical and chemical conditions which affect filtration. . . .

THIS paper will deal with the physical properties of fabric filter media, their relation to difficulties encountered in filtering operations, together with a description of the chief causes of these difficulties. In addition, some methods of determining the causes of the difficulties and a brief explanation of procedures to be followed in overcoming the troublesome conditions by correct filter design and control of operating conditions will be discussed. Also included will be a discussion of new types of filter fabric constructions and a description of their physical properties.

Little information is available describing the actual physical sequence of operations occurring at the surface of or within the fabric proper, during a filtering action.

A number of filter fabrics of various fibres have been used throughout the years with cotton being the more common. Cotton filter fabrics usually have the least initial cost. Various constructions are used throughout industry today and these vary from light muslin and twills to heavy duck. Canton flannel, a napped cloth, is used in the filtration of sewage sludges. Wool fabrics are used principally in mild acid operations and in certain sewage treatment plants where corrosive chemicals are used to condition the sludge for filtration. Linen, silk and rayon have been used in the past in fabric construction but have been displaced by fabrics constructed of plastic yarns.

Plastic yarns such as Orlon, Vinyon, Saran, and nylon have become increasingly popular because they have high mechanical strength and when properly selected resist corrosive chemical action. Furthermore, constructions more suited to the physical requirements of filter fabrics can be made with the strong continuous filament yarns.

Filter fabrics constructed of asbestos and glass fibers have been used and in fact still are in use to a moderate extent. Due to the nature of these fibers it has not been possible to construct fabrics for filtration that compare with plastic yarn constructions.

Filter Action

Considering the actual physical conditions existing at the surface of a filter fabric and also within the fabric construction, a definite series of conditions exists. It has long been known that where solids are to be filtered directly on a fabric in successive cycles the solids themselves must bridge the apertures of the fabric and form the filtering medium if the fabric is to remain pervious to flow. However, in the greater part of the available cloth constructions, most all of the fluid flow takes place through the yarn itself with only a small part of the flow passing through the apertures.

Theory of Operation

The physical conditions encountered with fabric filter media appear to fall in eight categories. It is often difficult to distinguish between one or the other since they frequently overlap and often more than one category is involved.

The eight categories are:

1. Loading of the yarn with solids; wherein filterable solids have become lodged within the yarn.
2. Fungus, bacterial, or algae growths on solid particles trapped within the yarn strands, or on the surface of the fabric.
3. Precipitation of solids from solution during the filtering cycle.
4. Poor underdrainage wherein the fabric is not supported with a pervious base.
5. Filtering above critical operating pressure for the material being handled.
6. Filtering at a concentration below which, the fabric apertures cannot be bridged.
7. Selective filtration of the finer constituent of a suspension containing solid particles varying widely in size.
8. Passage of excessive quantities of air through cracks in a filter cake causing precipitation of solids in the fabric by evaporation of the liquor in the cloth.

Each of the eight categories will be discussed in turn:

Loading Yarn with Solids

With respect to the first, a condition exists wherein the space between the filaments in a particular yarn strand becomes filled with filterable solid particles. When such solid particles are carried into the yarn, they become trapped and then are not free to move. Successive filtering cycles continually add to these, and finally the yarn is fully loaded with solids. Successive filter cakes produced on the fabric become difficult to separate from the fabric because the cake adheres to the solids caught between the yarn strands, not to the yarn itself. There is little adhesive action between filter cakes and yarn whether it be made of Orlon, Saran, Vinyon, nylon, cotton, or any other fiber. The result of loaded yarn strands can be recognized by the fact that while a filter cake can be formed readily, considerable difficulty is experienced in separating the cake from the fabric.

Bacterial Growths

The second category concerns the condition wherein the fabric becomes impervious owing to organic growths such as fungi, bacteria and algae. Such growths do not occur on the yarn but on solids trapped within the yarn or on the surface of the cloth. In fact, the growths occur on the solids at all times, even while the slurry is moving through pipe lines. When the solids become stationary the gelatinous growths, produced by these organisms, encompass any ma-

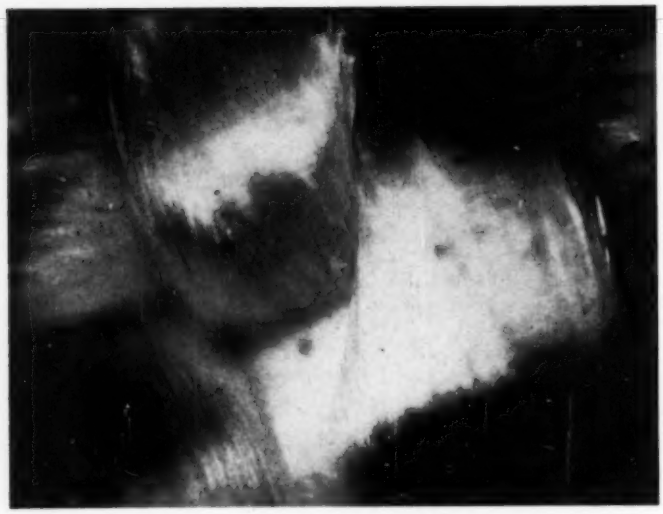


Fig. 1. Photomicrograph of loose twist yarn fabric construction.

terial in close proximity to the solid particle. Actual attack on the fabric itself is limited usually to constructions made of natural fibers and the action is slow, requiring days to become evident, whereas the gelatinous growths from the action of organisms on solid food matter trapped in the yarn will become evident within a single day. Attack on the fabric is usually evidenced by a general weakening of the fabric.

The first indication of organic growth is that the formation of a filter cake of uniform thickness is impossible, and full cake formation will occur only at random points on the filter surface. The condition progresses until no cake can be formed at all.

If the filtration operation is one in which solubles are washed out of the cake by application of wash water to the cake, it will be found that the displacement of the liquor from the cake requires increasingly longer amounts of time as the organic growth begins to seal off the yarn and apertures of the cloth. Usually difficulty with washing of the cake occurs long before trouble with cake formation is in evidence.

A simple method of determining whether organic growths are present is to place a small sample of the cloth on a laboratory test leaf, or secure it over the open top of a Buchner funnel, and subject it to vacuum, at the same time pour a small quantity of slurry over it with the cloth held at an incline to run off the excess. If no organic growth is present, a thin but uniform deposit of solids will be found on the fabric. If an organic growth exists, the deposition will be irregular and in the form of small buttons of cake located over the pervious spots in the fabric. There will be no cake formed in between the buttons.

If the fabric is then treated with a fungicide or a mild hypochlorite solution, the gelatinous growth will collapse and can be sluiced off with water. The fabric can then be subjected to vacuum again and a uniform cake will be formed when slurry is poured on it.

Precipitation of Solids from Solution

The effect of the third category, where precipitation of solids from solution occurs on solid particles trapped in between the yarn filaments or in the apertures of the fabric, is essentially identical to that occurring when organic growths cause the fabric to become impervious.

The removal of solubles from the cake by application of wash water will be the first difficulty encountered. Finally the deposition of cake will become retarded with an end point where no cake can be formed at all. Identifying this difficulty involves the same test as described for organic growths. If a precipitation is indicated, its nature may be determined by microscopic examination of the fabric, or by ashing the fabric in a muffle and conducting either a spectrographic or a chemical analysis of the ash.

Effect of Poor Underdrainage

The fourth category pertains to operational difficulties arising from inadequate underdrainage of the filter fabric, a condition where the fabric is not provided with a support of sufficient porosity. In certain instances, and more commonly with pressure filters, restricted drainage openings from the filtrate compartment will produce the same effect.

To perform satisfactorily, a filter fabric must be supported in such a way as to provide free escape of any solids that may pass through the cloth apertures at the beginning of each filtration cycle. If the solids passing through the fabric with this first surge cannot escape and become trapped in the apertures, the fabric will become impervious, since the solids are not free to move away. The addition of a more pervious support on top of the original support will usually provide a free path for the solids to escape in the first surge. Enlargement of the drainage area at the compartment outlet will overcome the difficulty encountered with restricted outlet openings.

Critical Pressure

The fifth category deals with difficulties encountered when filtration is carried out at a pressure above the critical operating pressure of the material being handled. With respect to any given material, there is a pressure at which the particular solid particles being filtered cannot form a bridge over the fabric aperture and as a result they collapse into the aperture and fill it up. Eventually the solid particles deposited by succeeding cycles are supported by them. When the filter cake is separated from the fabric, the particles that have collapsed into the aperture become locked in the more or less tortuous passage, occurring at the binding points of the warp and filling yarns.

Under these conditions apertures are gradually reduced in size to the point where flow of filtrate is seriously restricted. In certain instances the reduced size of the apertures causes selective filtration of fine particles only, resulting in a rapid reduction in filtration rate.

Microscopic examination of the fabric affords a satisfactory method of determining whether apertures have been reduced by such action.

A simple series of laboratory tests, using the particular fabric and slurry in question, will make it possible to determine at what pressure the apertures begin to load up. Tests conducted below a certain critical pressure will show unrestricted apertures when examined microscopically.

Critical Concentration

The sixth category involves the filtration of a given slurry at a concentration below the critical point wherein the solid particles approach the fabric apertures in widely spaced relation to each

other and instead of interfering with one another, to form a bridge, they enter the aperture. A certain number of particles will pass completely through the aperture, but some of them will become trapped at the binding points of the yarn strands gradually filling the aperture and producing the same effect as described when filtration is carried out at a pressure above the critical point. This category is closely associated with the preceding one and it can be stated that the critical operating pressure and critical point of solids concentration have a direct relation to each other.

Here again, microscopic examination of the fabric will afford the more satisfactory method of detection. Laboratory tests, conducted at varying degrees of solids concentration will indicate the point of concentration, below which, the solids do not form a bridge over the apertures.

Classification of Particles

The seventh category relates to selective filtration of solid particles, often referred to as classification of particles. This condition will be encountered when filtration is carried out on a suspension of solids containing particles having a wide variation in size. In operation, the finer particles often will bridge the apertures and form a thin, high resistant deposition, before the larger particles have been carried to the fabric. In addition, if the concentration of the suspension be close to the critical point, the fine solids may be unable to form a bridge over the aperature and will collapse into it, presenting the same condition as in the preceding category.

Should selective filtration be suspected or actually determined, there are two methods used to overcome it. The first is to employ a fabric having a larger aperture so that the finer particles will pass through and permit the larger particles to form a bridge. However, this procedure sometimes results in a cloudy filtrate. A second method is to increase the concentration of solids in the slurry so that the close proximity of particles to each other is sufficient to cause them to form a bridge over the apertures by interference. A direct indication of this condition can be obtained by noting whether the filter cake separates cleanly from the fabric at the time of discharge. If a heavy surface deposition remains on the fabric when the cake is discharged, classification may be suspected.

Of considerable interest is the fact that highly aerated slurries such as discharged from centrifugal classifiers or screens, frequently produce in effect, a variation in the category of selective filtration. Slurries discharged from such equipment, usually are in the form of an emulsion of air, liquor and solid particles. The colloidal and semicolloidal particles are usually found on the surface of the fine air bubbles. When filtration is carried out on a suspension of this nature, the bubbles collapse and deposit layers of fine solids of high resistance on the surface of the fabric or, in certain instances, within the apertures. Removal of the air by vacuum deairing equipment or by mechanical means is effective in overcoming this condition. In many instances the filtration rate after deaeration will be increased twofold.

In the operation of rotary vacuum filters where classification of the solid particles may occur with certain slurries, it is usually found that the larger particles tend to accumulate at the bottom of the filter tank. It is often possible to take advantage of this condition by delaying the point of application of the filtering vacuum so that filtration does not begin to take place until a particular compartment is actually submerged in the accumulation of larger particles. By so doing, the larger particles are deposited on the fabric first, bridging the apertures to form a filter medium. The finer constituents are then filtered on top of this deposition as the compartment reaches the upper zone of the slurry.

Effect of Air on Solids Precipitation

The eighth and final category pertains in particular to rotary vacuum filters where the filter cake cracks profusely during the dewatering cycle. Quite often there are certain amounts of solubles in the residual liquor in the filter fabric. When cracks occur in the cake, large volumes of air are drawn through the openings at a relatively high velocity. If the rotative speed of the filter is reduced below a critical point, the liquor in the fabric will be evaporated and any solubles present will be left in the fabric as a residue.

The result of such action will be identical to that experienced with precipitation of solids from solution, as discussed previously. In addition to the salting out of solubles, certain classes of solids do not readily remix with the suspending liquor passing through in the succeeding filtering cycle. In either instance, the fabric becomes impervious to flow of liquor and cake formation is greatly retarded. It is rather difficult to emulate the conditions in this category in the laboratory and the determination can best be made on the plant unit by observation.

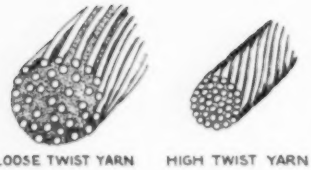
New Fabric Constructions

Considerable development work has been carried out recently on fabric filter media, with the idea of learning more about the physical performance of a filter fabric and to determine whether improved fabrics could be produced that would give better performance than obtainable with fabrics available at the time.

Interesting and materially helpful facts were brought to light during this investigation that permitted a better understanding of filter-fabrics performance.

It was established that with all fabrics of multifilament yarn construction existing at the time, a considerable portion of the flow of fluid in a filtering operation passed through the yarn strands

Fig. 2. Photomicrograph of high twist yarn fabric construction.



LOOSE TWIST YARN — VOIDS BETWEEN FILAMENTS ARE FILLED WITH SOLIDS

HIGH TWIST YARN — FILAMENTS ARE IN CLOSE RELATION TO EACH OTHER LEAVING FEW VOIDS

Fig. 3.

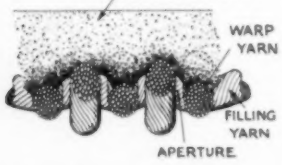
which are composed of a bundle of filaments or fibers and that a comparatively small amount of the flow actually passed through the fabric apertures.

Where closely woven fabrics of cotton, linen or natural fibers were used, the fibers being capable of absorbing water, swelled and closed off the apertures. In such instances, all filtration occurred on and through the yarn strands.

It was found that the tortuous passage existing in a bundle of filaments or fibers of which the yarn was composed, provided an ideal place for the entrapment of solids. Actual tests, conducted by the author, with fabrics woven from preloaded yarn, revealed that in a relatively closely woven cotton duck, or a light cotton muslin or twill fabric, 95 to 98% of the total flow of filtrate actually passed through the yarn strands with only 3 to 5% of the flow passing through the apertures of the fabric. Linen, silk, rayon and wool fabrics were nearly the same in action.

Consideration was given to the use of fabrics constructed of plastic yarns such as Orlon, Vinyon, nylon, and the like. Filter fabrics constructed of these plastic yarns at the time had shown marked advantages over fabrics constructed of natural fibers from a mechanical strength standpoint. However, from a physical operating standpoint, their useful life was not great enough to warrant adoption for general use, because of the higher cost.

While the fabrics maintained superior mechanical strength, they too would become inoperative after relatively short periods, unless constructed with large apertures resulting in poor retention.



SOLIDS HAVE MAINTAINED A BRIDGE SO THAT APERTURES REMAIN OPEN

Fig. 5.

It was concluded that if the fabric were constructed of a monofilament instead of a multifilament yarn, the difficulty with loading of the yarn with solid particles could be eliminated. However, it was found that tightly woven fabrics could not be constructed of single monofilament yarn unless the filaments were of such small diameter that the fabric had low mechanical strength. It was, therefore, decided to apply sufficient twist to the multifilament yarn to approach a monofilament yarn in effect and still retain some of the flexibility of a multifilament yarn for weaving purposes.

Development of High Twist Yarn Constructions

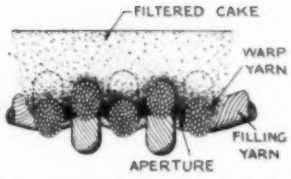
All available plastic filter fabrics at the time were constructed of yarn having one-half to three turns per inch of length. This is usually the amount of twist applied by the producer to hold the filaments together. Tests conducted with tightly woven plastic fabrics, wherein the yarn from which they were constructed had one-half to three turns per inch, showed that they were very little different from the cotton cloths in that from 95 to 98% of the flow of filtrate passed through the yarn strands and that the yarn rapidly loaded with solid particles.

Filter fabrics were then constructed of plastic yarn having successively higher number of turns per inch. When the turns were increased to 15 per inch, in a 60 or 70 denier yarn, tests conducted on this fabric demonstrated that only 70% of the flow of filtrate passed through the yarn strands and 30% passed through the apertures.

Further tests conducted with fabric constructed from 60 and 70 denier plastic yarn and having up to 35 turns per inch of length, demonstrated that only 2% of the flow of filtrate passed through the yarn strands and that 98% passed through the apertures.

In effect a fabric of plastic yarn had been constructed, with a multifilament yarn, essentially impervious to flow of fluid, and approaching a monofilament yarn in nature. Subsequent experiments demonstrated that the desired condition was one wherein the yarn was impervious to flow of filterable solids. Colloidal solids passed through the yarn since they were not filterable, under the conditions and the yarn did not become loaded with solid particles.

Many fabric constructions have been made using increasingly higher yarn deniers. It has been found that the number of turns necessary in the yarn, per inch of length, to create the condition wherein the yarn is impervious to flow of filterable solids, diminishes with the increase in yarn denier. In many instances, fewer than 35 turns per inch of length will create the desirable condition. This particular feature is the subject of patent, No. 2,551,175 recently issued.

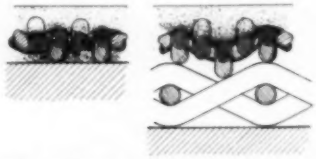


SOLIDS HAVE COLLAPSED INTO APERTURE INSTEAD OF FORMING BRIDGE

Fig. 4.

As an example of the increase in operating life of a fabric constructed of the highly twisted yarn it would be interesting to consider the operation of a continuous vacuum filter in a ceramic plant, producing wall tile. The material being handled is a suspension of several grades of clay and bonding agents, in water. The suspension contains approximately 40% solids. The temperature of the suspension is 120° F. Varying amounts of organic matter are present in the raw clay. Algae growths occur on the organic matter and indicate their presence on the filter fabric by a marked reduction in cake deposition. A light cotton fabric placed on this filter requires vigorous cleaning every 24 hrs. due to the fact that the yarn loads rapidly with clay solids and algae growths. At the end of a two-week period the yarn becomes so loaded that cleaning operations have no effect and it must be removed. A fabric constructed of 60 and 70 denier nylon yarn having only three turns per inch requires daily cleaning but will operate for a period of six weeks before yarn loading with clay particles and algae growth require removal. A fabric constructed of the same size nylon yarn but having 35 turns per inch will operate for 22 weeks, requiring only weekly cleaning to remove algae growth and is removed only because it has worn out mechanically.

Along with the features just described, there is a distinct advantage in the use of such fabrics on filters employing a compressed air blowback or fluid flush back to discharge the filter cake. With a fabric constructed of



SOLID PARTICLES PASSING THROUGH APERTURES CAN NOT ESCAPE

OPEN UNDERDRAINAGE ALLOWS SOLID PARTICLES PASSING THROUGH APERTURES TO ESCAPE

Fig. 6.

loosely twisted yarn, the reverse porosity is reduced to only a fraction of its original porosity when the yarn becomes loaded with solid particles. With high twist yarn construction, the original porosity of the fabric is maintained at all times so that cake discharge is rapid and thorough.

Comment on Illustrations

Figure 1 is a photomicrograph of a filter fabric, taken with a magnification of 75 diam. The fabric shown is constructed of 600 denier Orlon yarn having one-half turn per inch of length. In such a construction it will be noted that adjacent yarn strands are packed tightly together and that any apertures that may exist, are extremely small.

The filtration action must therefore, for the most part, take place on and through the yarn strands. It is obvious that most all the fluid flow will pass through the yarn strands. The bundle of filaments presents a tortuous path, through which the fluid must flow, with the result that filterable solids are carried into the voids between the individual yarn filaments and are then not free to move in any direction. Yarn of this type tends to load with solid particles rapidly and the fabric soon becomes impervious to flow of fluid excepting through the few small apertures that remain between adjacent yarn strands.

Another photomicrograph (Fig. 2) of a filter fabric taken also with a magnification of 75 diam. shows a fabric also constructed of 600 denier Orlon yarn. The yarn used in this construction has a twist of 25 turns per inch. With this construction the highly twisted dense yarn strands are rigid to the extent that they do not pack tightly together, except at the binding points. The advantage here is that definite apertures exist with the result that it is considerably more pervious to flow of fluid than the construction shown in Figure 1.

The diameter of the yarn in this fabric is roughly 60% of the diameter of the one-half turn yarn used in the construction of the fabric shown in Figure 1, although the yarn deniers are identical. This gives some indication of the amount of reduction in the volume of voids within the yarn. There is a negligible flow of fluid through the yarn in this fabric since nearly all voids have been filled by compression of the yarn filaments in the twisting operation.

Figure 3, is a comparison drawn between loosely twisted and highly twisted yarns, shown graphically. With the loosely twisted yarn there are many voids between filaments and an appreciable flow of fluid is able to pass through these voids. The sketch depicts a condition wherein the voids between filaments have become filled with solid particles and the yarn strand is essentially impervious to flow of fluid. A deposition of cake filtered onto this yarn will adhere to the solid mass of material imbedded in the yarn; this will hamper cake discharge.

If all or part of the particles are of a material on which fungi, algae or bacteria will propagate, it can easily be understood that the gelatinous growth produced by such organisms, will soon encompass the yarn and apertures existing between the adjacent yarn strands. However, since yarn having such wide spaces between filaments is highly compressible, it is evident that when it is woven into a fabric, it will deform and tend to fill in the space between adjacent yarn strands, closing off the greater part of the aperatures that would have existed if the yarn were not compressible.

In the highly twisted yarn, the voids between filaments have been almost completely filled up. The flow of fluid through this yarn will be negligible and any filterable particles will be stopped at the surface of the yarn. Colloidal solids can, of course, pass through the small spaces between filaments but since they are not filterable under the conditions, they will pass on through the yarn and escape with the main fluid.

Figure 4 shows the condition wherein solid particles have failed to bridge properly the aperture and have collapsed and moved well down into it. The relative yarn diameters are not shown in correct proportion but were drawn in this manner to present a clearer picture. The drawing represents a section through a fabric, at a point halfway between and parallel with the filling yarn strands. It will be noted that the cake formation has taken place on the solids locked in the apertures and that the deposition in the apertures has traversed almost to the bottom of the filling yarn. Actually the deposition in the aperture is formed well under the warp yarn at the points where it rests on the filling yarn. The deposition in the aperture is locked in place and cannot be removed when the filter cake is discharged from the fabric. Such a condition can be caused by filtering above the critical pressure or at too low a consistency. Furthermore a collapsing floc will cause the same effect.

Figure 5 shows the condition existing when the solids to be filtered properly bridge the apertures. Here again the relative yarn diameters and aperture sizes are not shown in correct proportion but rather to present a clearer picture. It can be noted that the cake formation does not extend down into the aperture and, therefore, does not lock underneath the warp yarn. When the deposition of cake is discharged from the fabric, essentially all the solids will leave with it.

These figures, namely Figures 4 and 5, portray conditions existing with high twist yarn constructions wherein the filterable solids are all resting on the surface of the yarn. It would be easy to visualize the condition existing if the fabric were constructed of loosely twisted yarn wherein the cake can adhere not only to solids locked within the aperture but also to solids trapped within the yarn filaments.

In Figure 6 an attempt has been made to demonstrate the condition existing when the filter fabric is not provided with a pervious support. This condition is quite common with many commercial filters in operation throughout industry.

On the left, a section of fabric is shown resting on a flat, undrained surface. All fluid and solid particles passing through the apertures must travel a considerable distance underneath the fabric before finding an escape passage. The relative sizes of the fabric and supporting surface are essentially those that would exist if a fabric 1/16 in. thick were resting on a slotted surface having ribs that are ½ in. wide. Solid particles passing through the fabric apertures are not free to escape and become trapped in the rather tortuous passage existing between the yarn strands and the supporting surface. The solids eventually accumulate beneath the fabric until they damp off all flow of fluid. As a rule, any supporting surface for a fabric should not have undrained areas greater in width than ¼ in. if escape of the solids is to take place readily. This condition is troublesome if the solid particles being filtered fail to bridge the apertures of the fabric for one reason or another. Furthermore, it will promote difficulty with organic growths or precipitation from solution where such conditions are likely to occur.

Also in Figure 6 is shown a fabric supported by a pervious underdrainage. The relative sizes of fabric and supporting members are those existing wherein a fabric 1/16 in. in thickness is to be supported by a 14-mesh screen of metal or plastic. It is obvious that a fabric supported by a pervious member of this kind will be free from the difficulties considered since escape of solid particles passing through the fabric apertures is not restricted.

Acknowledgment

Thanks are extended to the members of the development engineering department of the Titanium Division of the National Lead Co. for their cooperation and assistance in further proving many features described in this discussion.

IMPROVING FILTRATION AND FILTRATION RATES

Chemical and Mechanical Preparation of Filter Feed Slurries

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CHARLES FUHRMEISTER, JR., has been manager of the Eastern Division of the Oliver United Filters, Inc., Engineers, of New York, for more than 20 years. He received his education at Cooper Union in New York. For more than 30 years Mr. Fuhrmeister has spent his time and energies in an active participation in diversified filtration work in the process industries. The fields of his activities and interests include the chemical, pulp and paper, metallurgical, food products, petroleum, and general industrial fields. The accompanying article testifies to his wide knowledge of the influences affecting filtration rates.

DETAILS of physical and chemical conditions which affect filtration rates, and mechanical means of handling slurries which improve filtration results are of prime interest to practicing chemical engineers.

The facts and information presented here are on a practical basis, having been assembled from field experiences. They show the usual qualitative and quantitative influence on filtration in general, and involve the following:

1. Effect of temperature change on rate of filtration of solids suspended in water.
2. Effect of temperature change on rate of filtration of solids suspended in 50° Brix sugar solution.
3. Effect of change in slurry density (% solids in suspension) on rate of filtration.
4. Effect of change in viscosity on rate of filtration.
5. Effect of particle size of suspended solids on rate of filtration.
6. Effect of pH conditioning on rate of filtration.
7. Effect of desliming.
8. Filter aids.
9. Mechanical feeders.

Filtration, as discussed here, is the separation of solids from liquids by mechanical means. Since the volume of liquid to be handled must pass through the filter, the desirable step is to cause the highest rate of flow, and to reduce to a minimum the volume to be handled.

Usually increase in temperature of a given slurry reduces viscosity, and lower viscosities increase rates of filtration.

Figure 1 shows the increase in rate of filtration in terms of gallons per square foot, and in pounds per square foot of filter area when filtering an aqueous slurry of 25% by weight, calcium carbonate. It also shows the increase in the solids content of the filter cake as the slurry temperature increased. It can be seen that the flow rate increase was almost constant. The rate increased 100% with a 90° F. rise in temperature, or slightly better than 1%/° F. The tonnage rate increase was slightly better than the volume increase. The increase in the solids content of the filter cake is interesting to note because it goes along with the accelerated rate of filtration. It is probably due to the higher filtrate velocity, causing formation of the denser filter cake.

In Figure 2 the effect of temperature change is indicated on the rate of filtration of a slurry of 25% solids calcium carbonate, by weight, suspended in a 50° Brix sugar solution. The increase in rate of filtration is similar to that shown in Figure 1 demonstrating that the effect of the temperature change is also found in liquids of higher specific gravities. Rate of increase indicated is slightly better than 1%/° F.

The effect of changes in concentrations of suspended solids calcium carbonate with slurries at different temperatures can be seen in Figure 3; here temperature was introduced as a check on the information provided by Figure 1. The curves are almost parallel at the two different temperatures, and an observation can be made that the progression of these curves is similar to those of Figure 1. These curves thus show the rapid increase obtained in the tonnage rate as the percentage of suspended solids is increased. Trebling the solids

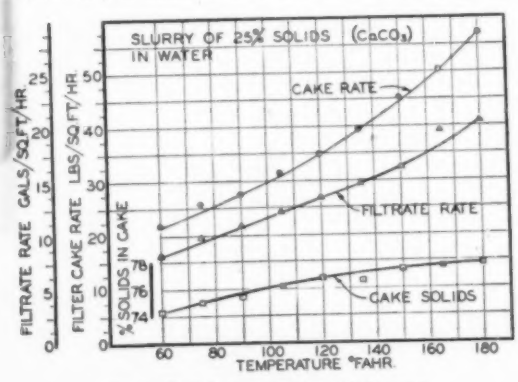


Fig. 1. Effect of temperature on filtration rate.

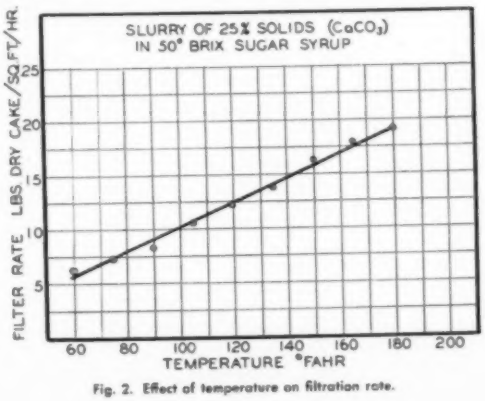


Fig. 2. Effect of temperature on filtration rate.

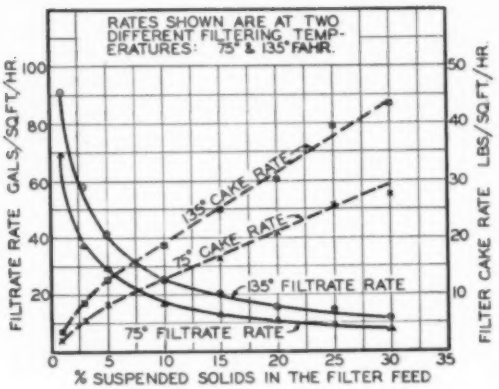

RATES SHOWN ARE AT TWO DIFFERENT FILTERING TEMPERATURES: 75° & 135°FAHR.
FILTRATE RATE GALS/SQ FT/HR.
FILTER CAKE RATE LBS/SQ FT/HR.
135° CAKE RATE
75° CAKE RATE
135° FILTRATE RATE
75° FILTRATE RATE
% SUSPENDED SOLIDS IN THE FILTER FEED

Fig. 3. Effect of slurry density on filtration rate.

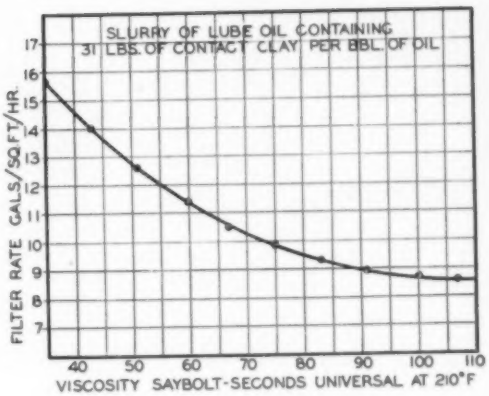

SLURRY OF LUBE OIL CONTAINING 31 LBS. OF CONTACT CLAY PER BBL. OF OIL
FILTER RATE GALS/SQ FT/HR.
VISCOSITY SAYBOLT-SECONDS UNIVERSAL AT 210°F

Fig. 4. Effect of viscosity on filtration rate.

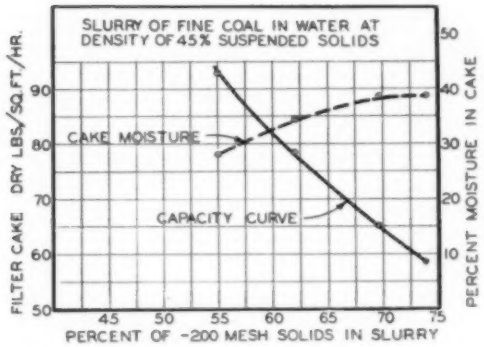

SLURRY OF FINE COAL IN WATER AT DENSITY OF 45% SUSPENDED SOLIDS
FILTER CAKE DRY LBS/SQ FT/HR.
PERCENT MOISTURE IN CAKE
CAKE MOISTURE
CAPACITY CURVE
PERCENT OF -200 MESH SOLIDS IN SLURRY

Fig. 5. Effect of particle size of solids in the slurry on filtration rates.

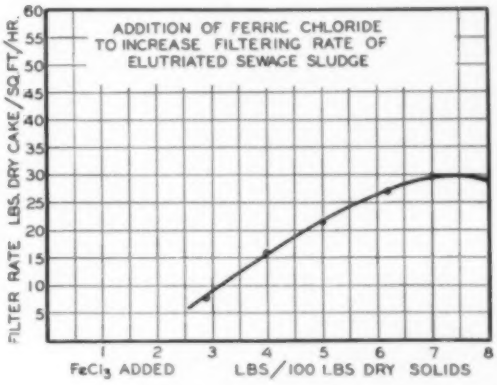

ADDITION OF FERRIC CHLORIDE TO INCREASE FILTERING RATE OF ELUTRIATED SEWAGE SLUDGE
FILTER RATE LBS. DRY CAKE/SQ FT/HR.
FeCl3 ADDED
LBS/100 LBS DRY SOLIDS

Fig. 6. Effect of pH conditioning on filtration rate.

content approximately doubled the tonnage rate. Thus, when possible, it is advisable to thicken, within limits, slurries to be filtered to reduce the size of the filter equipment required. This thickening may be by means of gravity thickeners, or other economical or practical means.

Figure 4 illustrates the difference in filtration rate due to difference in viscosity. This example is based on filtration of lubricating oil in which a contact clay was suspended. These oils contained 31 lb. clay/42-gal. barrel. Thus, this drawing shows that the light oils—those having lower viscosities—filtered more rapidly although containing the same quantity of solids in suspension.

The difference in filtration rates and moistures in the filter cake due to reduction in particle size of a given material is illustrated in Figure 5. In this case the material is bituminous coal fines from coal washeries. The sharp drop in the tonnage rate compared with the percentage of −200-mesh size present can be noted. A 25% increase in the −200 size reduced the tonnage rate 30% and increased the moisture content 38%. Similar results may be expected when filtering other materials, but the variation in rate need not be the same as the example just cited.

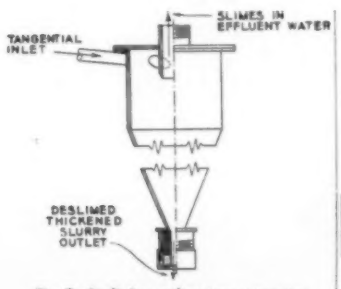


Fig. 7. Desliming cyclone-type separator.

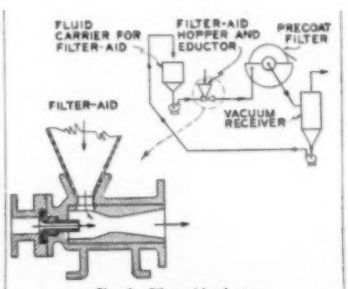


Fig. 8. Filter-aid eductor.

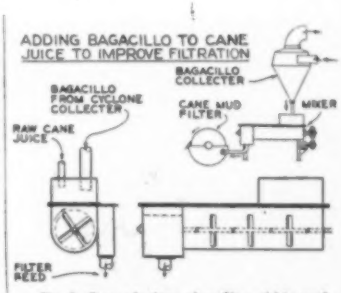


Fig. 9. Type of mixer when filter aid is used.

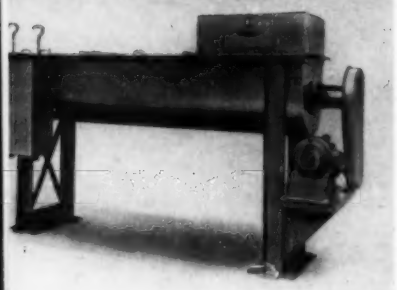
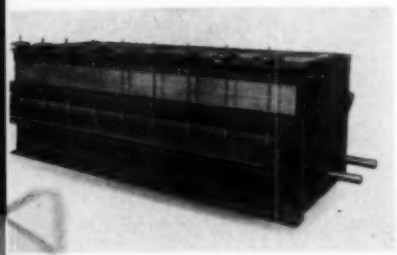
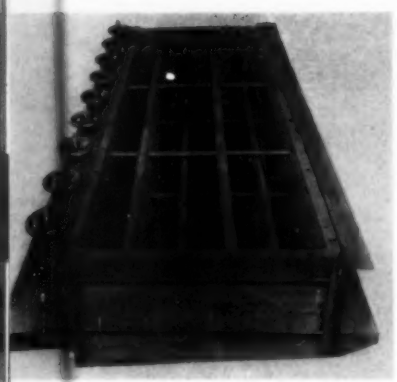


Fig. 10. Another view of mixer shown in Fig. 9.

Figs. 12-14. Flow boxes for providing uniform constant flow of pulp. ▼





A figure, namely 6, showing the effect of change in pH conditioning of sewage sludge is based on data from "Sewage Treatment Works" by C. E. Keefer (McGraw-Hill). Specifically it illustrates the effect on filter capacity by adding varying percentages of ferric chloride to an elutriated, digested sewage sludge prior to filtration. The curve shows that at first the addition of a given amount of the conditioning agent caused a 100% increase in tonnage rate, but continued addition of the same amount did not cause the same increase and over-treatment was soon reached. Lime is used as the conditioning agent with digested and raw sludges and is also frequently employed for neutralization and conditioning of plant wastes, thus conditioning the wastes for settling and subsequent filtration.

A simple cone bottom desliming cyclone-type separator is shown in Figure 7. In the filtration of some materials, such as magnetic iron ores, the wet ground and treated ores are dewatered by filtration prior to sintering or shipment. The slurry fed to the filter is dense—approximately 70% solids by weight—and the solids are of approximately 5.0 sp.gr., but traces of slimy material, such as apatite, are present. This slimy material will quickly blind the filter medium, and the capacity of the filter will fall off to practically zero in a matter of hours. However, if the slurry from the conditioners is passed through a separator of the type illustrated with an ample flow of water, the slimes will move along with the water, and the solids leaving from the bottom of the separator, will be practically free from slimes. In this case, the solids were about 90% + 200 mesh. The slimes were contained in the −200-mesh portion but to a small extent only. There are several different types of desliming machines, and their application and use are wide and growing, especially in the mining fields.

Figure 8 illustrates a type of filter-aid eductor which may be employed for introducing the aid into the slurry stream, or for use when applying a precoat to a filter. Most filter aids degrade quickly when handled in slurry form by a centrifugal pump. As a result, the filter cake formed is denser and the rate of filtration is lower.

Use of an eductor of this type has in many cases improved filtration rates as well as reduced maintenance of the filter feed equipment.

The ratio of filter aid to solids present varies with the conditions but seldom is higher than one-to-one by weight.

Another type of mixer is illustrated in Figure 9. This is used when adding a filter aid, such as bagacillo, to the cane sugar slurry known as cachaza mud. In this case, the filter aid is added to a thickener underflow in a mixer as shown, in order to make the slurry more filterable. Without this addition, this particular slurry is almost unfilterable. In this case, this aid not only functions as a spacer, but also as an adsorption agent. The quantity employed is approximately 1500 lb. of bagacillo as obtained/100 tons of cane milled. The ratio of bagacillo to the solids with which it is mixed is quite variable, depending much upon local conditions. Another view of this mixer is shown in Figure 10.

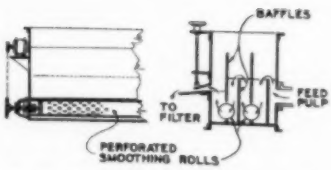


Fig. 11. Mechanical preparation of paper pulps for feeding to filters.

In Figure 11 a type of flow box is depicted employed for providing a uniform constant flow of pulp across the width of the filter and free from bundles of fibers. These fibers have a definite attraction for one another, and unless kept dispersed, will build up bundles which cause a lumpy sheet formation.

The box shown in Figure 11 and in Figures 12, 13 and 14 is one found satisfactory for feeding a filter used for forming insulation wall board. The sheet formed must be well felted, uniform in caliper, and constant in weight.

A typical installation forms 500,000 sq.ft. of ½-in. finished thickness board/24 hrs. This is accomplished at a lineal speed of from 30 ft. to more than 50 ft./min. while the machine is handling up to 5000 gal. feed slurry/min. The sheet must weigh about 680 lb./1000 sq.ft. and must caliper 0.500 in. ± .0075 in.

The rotating perforated agitator rolls keep the fibers apart and the longitudinal baffles control the flow. The adjustable gate over the discharge apron distributes the flow evenly across the full length of the vat.

It is necessary when handling fibrous material to exclude air from all of the handling equipment. Air, especially if

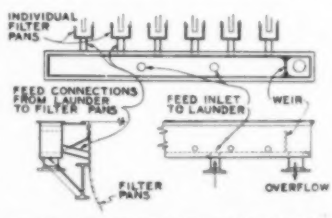


Fig. 15. Flow box with disc-type filter feed distribution to prevent classification of feed.

introduced into alkaline or soapy pulps, will cause large amounts of foam. Pulp slurries containing air when fed to filters will not form satisfactory sheets. The sheet (filter cake) will be soft, unfelted and mushy. Such a formation cannot be washed free from impurities or otherwise processed. In the recovery of pulp cooking liquors by the washing of cooked pulps on filters, large degassing tanks are employed to permit the degassing of the cooking liquors or filtrates before reuse. Extreme care is exercised so no air will be mixed with the pulp on its way from the digesters to the washing filters.

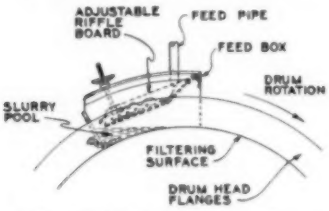


Fig. 17. Filter feed distribution for slurries with fast settling solids.

The practice of providing uniform slurry feed evenly distributed to the filter is most important in all cases. Best operating results can only be obtained by providing a continuous flow of uniform consistency to all of the filter area. Figures 15-16 show a flow box employed with a disc-type filter, when handling solids which are heavy and which may settle or classify. This type of feed box has been found most satisfactory for feeding blast furnace flue dust or coal washery slurries to continuous filters.

An arrangement for feeding fast-filtering, fast-settling solids slurry to a top feed filter of the type employed for partially or completely drying the solids is drawn in Figure 17.

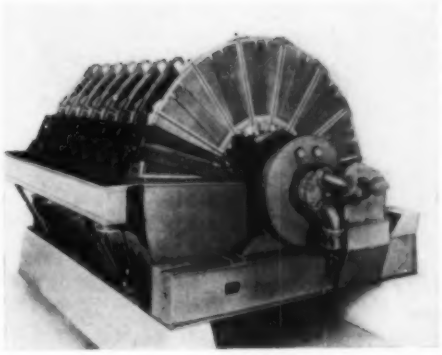


Fig. 16. Flow box with disc-type filter feed distribution to prevent classification of feed.

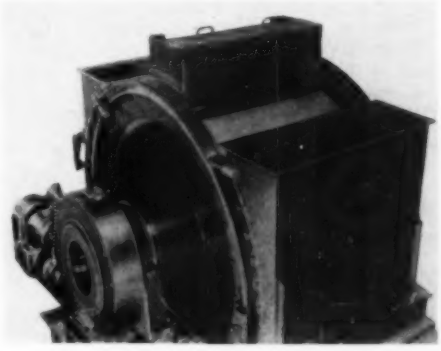


Fig. 18. Top feed filter with feed box in place.

Since the drying is accomplished by the passage of preheated gases through the filter cake, it is necessary that the filter cake be well-formed and uniform in thickness. Thus, the solids must be fed onto the filter at a constant rate in terms of volume of slurry and weight

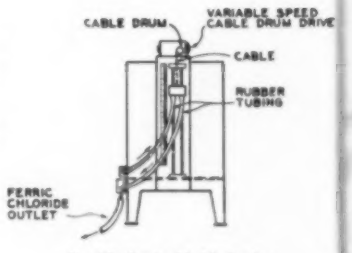


Fig. 19. Ferric chloride feeder.

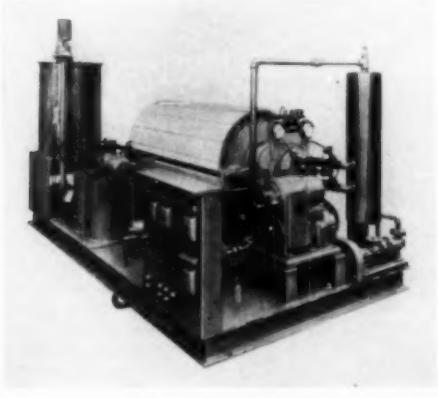


Fig. 20. Package-type filter.

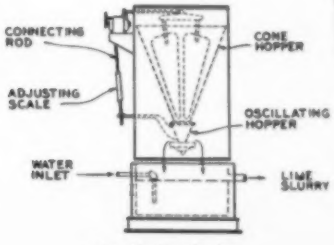


Fig. 21. Lime feeder.

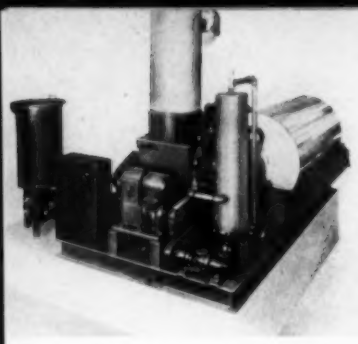


Fig. 22. Package-type continuous filter.

of solids. Further, the feed must be perfectly distributed across the width of the filter. This type of feeder has a distributor plate provided with suitable baffles. A seal is provided so the slurry will be contained within the cake formation area. In Figure 18 the top feed filter appears with the feed box in place.

Figures 19 and 20 illustrate a type of ferric chloride feeder employed for conditioning sewage slurries. The ferric chloride solution is prepared in a make-up tank, and a supply is then placed into this feeder tank. The rate of flow of untreated filter feed controls the rate at which the solution is added. The drive on the feeder lowers the small weir box which causes a flow of solution into it by gravity, and thence into the slurry at the filter.

Figure 20 illustrates a package-type filter with ferric chloride feeder.

The supply of lime (See dry lime feeder, Fig. 21) is placed in the container. The container is fitted with slowly revolving paddles which prevent bridging of the lime in the tank. An oscillating device causes constant discharge of the dry lime at the desired rate into a receptacle below for mixing with water. After this hydration step, the lime slurry is mixed with the filter feed at the filter.

The illustration, Figure 22, is a package-type Oliver continuous filter fitted with a dry lime feeder.

The Oliver horizontal filter, shown on Figure 23, which in contrast to other continuous vacuum filters rotates on a horizontal plane around a vertical axis,

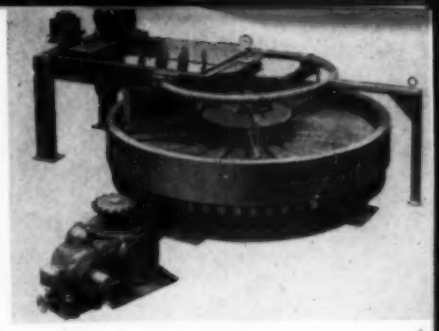
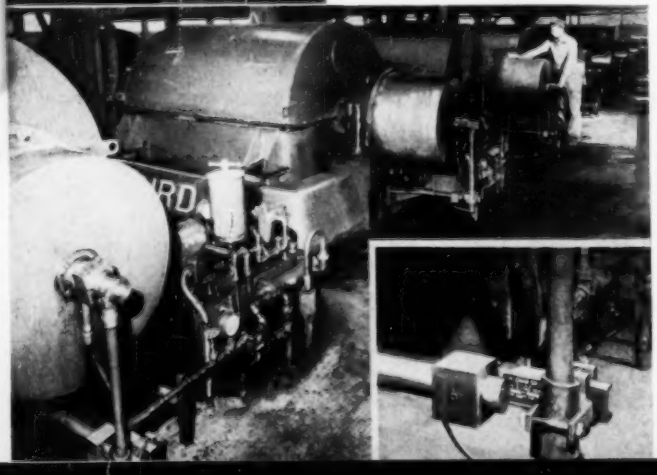


Fig. 23. Oliver horizontal filter.

is fed by means of a fan tail pipe with the outlet close to the filter deck. The pulp usually impinges on the dam separating the feed zone from the discharge area and then spreads out laterally in all directions so as to form a uniformly thick cake on the horizontal deck. Classification of solids, if any, assists in forming a suitable cake and minimizes cloth blinding.

(End of Filtration Symposium)



A novel method of controlling loading conditions of centrifugal dewatering filters for fine coal and slate is used at the Robena mine of the H. C. Frick Coke Co. The centrifugal filters shown here handle 300 tons of coal an hour in particle sizes up to ¼ in. and load variations are smoothed out by means of resistance wire strain gages bonded to cantilever load-beams.

The torque required to operate each separator, driven by a 150 hp. motor, transmits a push against a load-beam by means of a vertical arm extending down from one end of a horizontal shaft at the end of the machine. The arm is retained loosely by a clevis clamped on one end of the load-beam as shown.

Photos courtesy of Baldwin Locomotive Works

The load-beam is supported by a bracket extending out from the base of the machine.

The push of the arm strains the outer fibers of the beam on which the strain gages are bonded on both sides, stretches or compresses the wires of the gages, and changes their electrical resistance. This change of resistance is transmitted a considerable distance to a recording controller on the next floor above, where it is translated and recorded as pounds of load, thus showing the conditions under which the separator is operating at all times.

If the filter load exceeds a set value, such as 300 lbs. or 15% above normal, as measured by resistance changes in the gages, the feed is cut off automatically until the machine has cleared itself. If the load continues to increase, however, beyond a maximum safe value, not only is the feed cut off but the machine is stopped. It is also stopped automatically if the torque load becomes zero, as when a shear pin breaks in the drive.

The top picture shows a standardized control of centrifugal filters for dewatering coal by means of a force-beam. Strain gages on this beam are the key elements of the electric circuit of the controller and recorder, which is being read by the operator. Pictures show an installation in the Champion Coal preparation plant of Pittsburgh Coal Co.

EXTRACTIVE DISTILLATION

DESIGN AND APPLICATION

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This paper will consider the extractive distillation column that has two sections and where the extractant flows from one extremity to the other, flowing countercurrent to the first key in one section and cocurrent with the second key in the other section of the column. The volatility of the extractant may be less than, greater than, or between the volatilities of the keys. It may azeotrope with one or both; the only practical restriction is that any azeotrope formed can be easily broken or is a product itself.

Many fundamentals are overlooked or neglected in the usual simple distillation problem and in the simplified treatment of complex distillation problems. These fundamentals must be recognized to use and understand extractive distillation to the fullest extent.

EXTRACTIVE distillation is an important tool, particularly in the separation and purification of chemicals produced synthetically and in the separation of other closely boiling compounds. Broadly, extractive distillation is distillation in which the volatility of the key components are altered by the addition of a third component.

Several methods (*1, 3, 5*) have been proposed for solving extractive or azeotropic distillation problems, but they are all on an entrainer free or modified basis and fail to show exactly what occurs in the column.

Extractive and ternary distillation problems are presented here in accurate graphical solutions. The graphical solution is obviously exact and leaves one with a clear mental picture of what occurs in a ternary or extractive distillation column, just as does the McCabe-Thiele (*4*) graphical solution for binary distillation columns. Also, as with binary or simple distillations, once this picture is complete, algebraic methods may be properly applied and used with confidence for certain portions of the column.

Three Examples Presented

The first of the three examples presented on the ternary system methanol, ethanol, and water will be a simple distillation where methanol is the overhead product and ethanol-water, the bottoms product. The second example will be one of extractive distillation in which ethanol-water is the overhead product and methanol-water is a side stream near the base. The third example will also be an extractive distillation where the overhead product is anhydrous methanol-ethanol and the bottoms, methanol-water.

However, before proceeding with the examples, certain fundamentals must be established.

Basic Fundamentals

To separate a binary mixture the feed is introduced in the center of a column, one component is taken overhead and the other is drawn off at the base. That portion of the column above the feed is normally referred to as the rectifying section, and the portion below the feed is called the stripping or exhausting section. Thus, a section of a column is that portion of the column between successive points where material is either introduced or withdrawn. The term operating line as used in the McCabe-Thiele and nearly every other method for determining the number of plates required in a distillation column is familiar to everyone. There is a different operating line for each section of the column. It is derived by total and particular component material balance and is valid for each component, however complicated the mixture being handled. The operating line for the rectifying section in the above column intersects the 45° diagonal $x = y$ line at the composition of the overhead product. This point of intersection of the operating line, with the $x = y$ line, will be called the Focal Point. The focal point for Component A for the rectifying section is the composition of Component A in the distillate. The focal point for Component B in the rectifying section is the composition of Component B in the distillate. Thus, each component has a focal point in each section of the column no matter how complicated the mixture or how many sections there are in the column.

Focal Point. For example, consider the column in Figure *AA*, which has two feeds F_1 and F_2, a top product D, a side stream P, and a bottom product W. The product is withdrawn from the condenser. The feed F_1 is fed onto the top plate. The feed F_2 is fed onto an intermediate plate. The side stream is withdrawn from an intermediate plate below the F_2 feed plate. The bottoms W are withdrawn from the base of the column. A reboiler is used to furnish the vapor at the base. The column has three sections. Section I is the top plate to and including the plate above the F_2 feed plate. Section II is F_2 feed plate to and including the plate from which side stream P is withdrawn. Section III is from the plate below the side stream plate to the base of the column.

Circle 1 is drawn below any plate n_1 in Section I and around the top of the column.

By material balance for any particular component A of any number present:

† Badger Process Division.

$$V_{n1-1}Y_{An1-1} + F_1X_{AF1} = O_{n1}X_{An1} + DX_{AD}$$

$$Y_{An1-1} = \frac{O_{n1}}{V_{n1-1}}X_{An1} + \frac{DX_{AD}}{V_{n1-1}} - \frac{F_1X_{AF1}}{V_{n1-1}}$$

which is the equation of the so-called operating line for Component A in Section I.

Solving this equation for the intersection with the $X = Y$ line by letting $X_{An1} = Y_{An1-1}$

$$Y_{An1-1} = \frac{DX_{AD} - F_1X_{AF1}}{V_{n1-1} - O_{n1}}$$

by total material balance in Circle 1

$$V_{n1-1} - O_{n1} = D - F_1$$

therefore

$$X_{An1} = Y_{An1-1} = \frac{DX_{AD} - F_1X_{AF1}}{D - F_1}$$

= focal point for Component A in Sect. I

Thus, by drawing a circle below any plate in a section and around the extremities of the column, then writing a particular component material balance for the streams that cross the circle, the equation of the operating line is obtained. Solving this equation for the intersection with the 45° diagonal by letting $X = Y$ and eliminating O and V by the total material balance in the circle gives the focal point for that section.

Or, as a short cut, merely write the total material balance as follows:

$$V_{n1-1} + F_1 = O_{n1} + D$$

Put O and V alone on the left side with the remainder of the terms on the right side:

$$V_{n1-1} - O_{n1} = D - F_1$$

Multiply each term on the right side by its mole fraction, X if liquid and Y if vapor

$$DX_D - F_1X_{F1}$$

Now the focal point equals the above divided by the right side of the total material balance equations with V and O on the left.

$$X = Y = \frac{DX_D - F_1X_{F1}}{D - F_1}$$

= focal point for Section I.

By using the appropriate mole fractions in the numerator, the focal point for each component for Section I is obtained, for instance:

Component A focal point =

$$\frac{DX_{AD} - F_1X_{AF1}}{D - F_1}$$

Component B focal point =

$$\frac{DX_{BD} - F_1X_{BF1}}{D - F_1}$$

etc., for each component.

If a circle were drawn below plate n_1 and around the base of the column, the focal point for Section I would be expressed by streams entering and leaving the column below this plate.

For instance:

$$V_{n1-1} + W + P = O_{n1} + F_2$$

and

$$V_{n1-1} - O_{n1} = F_2 - W - P$$

$$X = Y = \frac{F_2X_{F_2} - W_{XW} - P_{XP}}{F_2 - W - P}$$

which, of course, equals $\frac{DX_D - F_1X_{F1}}{D - F_1}$

(Note that the focal point is independent of O and V within the column, but is determined entirely by the streams that enter and leave the column.)

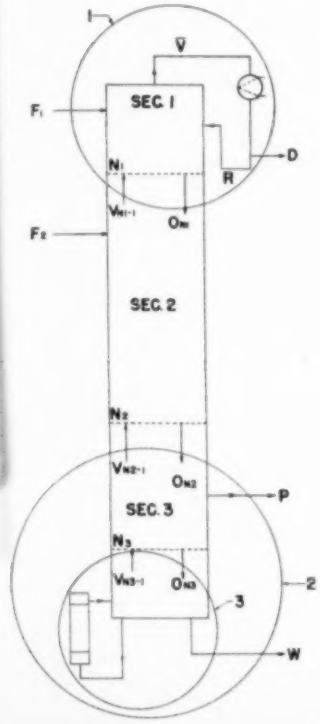


Fig. AA.

1. $Y_{AN1-1} = \frac{O_{N1}X_{AN1}}{V_{N1-1}} + \frac{DX_{AD} - F_1X_{AF_1}}{V_{N1-1}}$

1a. $X_{AN1} = Y_{AN1-1} = \frac{DX_{AD} - F_1X_{AF_1}}{D - F_1}$

2. $Y_{AN2-1} = \frac{O_{N2}X_{AN2}}{V_{N2-1}} - \frac{PX_{AP} + WX_{AW}}{V_{N2-1}}$

2a. $X_{AN2} = Y_{AN2-1} = \frac{PX_{AP} + WX_{AW}}{P + W}$

3. $Y_{AN3-1} = \frac{O_{N3}X_{AN3}}{V_{N3-1}} - \frac{WX_{AW}}{V_{N3-1}}$

3a. $X_{AN3} = Y_{AN3-1} = X_{AW}$

Other Basic Fundamentals

In the preceding discussion, nothing has been said about the constancy of either O or V. Only in rare cases is the O/V below every plate in a given section of the column exactly the same. When O and V vary within a given section, O/V is not the slope of the so-called operating line. Instead, O/V below any plate is the slope of a material balance line passing through the focal point and intersecting the operating line at the point X_B, $Y_B = 1$. For this reason, one should visualize an operating line for each plate and not a single line for a whole section. The plate operating lines would be a series of lines radiating from the focal point. In most columns, the ratio, O/V, varies so little in a given section that it may be considered constant. This constant value must be selected at the critical point in the section. For example, in the stripping section of a column where the value of O/V increases as one proceeds up the column from the base, the critical point is just below the feed plate. In this case, if the O/V just below the feed plate is above the minimum O/V, the column will not operate as planned even though the average O/V and the O/V below every other plate is well below the minimum.

In extractive distillation columns, the boiling point of the feed often is con-

siderably different from the temperature on the feed plate. The q line concept is of little use in this case when based upon the feed. The locus of the intersection of the line through the focal point for Section I with slope (O from plate above F_2 feed)/(V to plate above F_2 feed) and the line through the focal point for Section II with a slope (O from F_2 feed plate)/(V to F_2 feed plate) will be on the line through $X = Y = X_{F_2}$ with slope of (O plate above F_2 feed $- O$ from F_2 feed plate)/(V to plate above F_2 feed $- V$ to F_2 feed plate). If F_2 is at the temperature of F_2 feed plate $\Delta O/\Delta V = F_2/0 = \infty$ and the intersection will, of course, be X_{F_2}. Also, the line through the focal point for Section III with slope O from top plate of Section III/V to top plate of Section III will intersect the O/V line above, through the focal point † for Section I along the line through

$$X = Y = \frac{F_2 X_{F_2} - P X_P}{F_2 - P}$$

with slope of $\Delta O/\Delta V$.

$$\frac{\Delta O}{\Delta V} = \frac{O \text{ from bottom plate of Section I} - O \text{ from top plate of Section III}}{V \text{ to bottom plate of Section I} - V \text{ to top plate of Section III}}$$

It is important to remember that the vapor composition to any plate and the composition of the liquid from that plate are coordinates of a point on the line through the focal point with slope = (O from plate)/(V to plate). Thus, if the concentration of component A in the liquid to any plate n is held constant in some manner, the concentration of A in the vapor from plate n will vary only if O to plate n and V from plate n vary. Likewise, the concentration of A in the liquid from plate n will vary only if the O from plate n and V to plate n vary. With this fact in mind, it is possible to shift the operating line by using controlled vapor or liquid concentrations to go beyond azeotropic or pinch concentrations.

In a binary mixture, the composition of the vapor leaving a liquid under equilibrium conditions is uniquely determined by the composition of a single component in the liquid. This makes possible the familiar McCabe-Thiele step-off method for determining the theoretical plates for a binary separation from a single X vs. Y diagram. When dealing with more complicated mixtures, this method breaks down for the simple reason that the equilibrium composition of the vapor is not a unique function of the concentration of but one component in the liquid. The problem of determining the plates required for a ternary separation can be solved graphically by plotting the $X - Y$ data in a particular manner on two plots and by using the plots alternately to step off the theoretical plates.

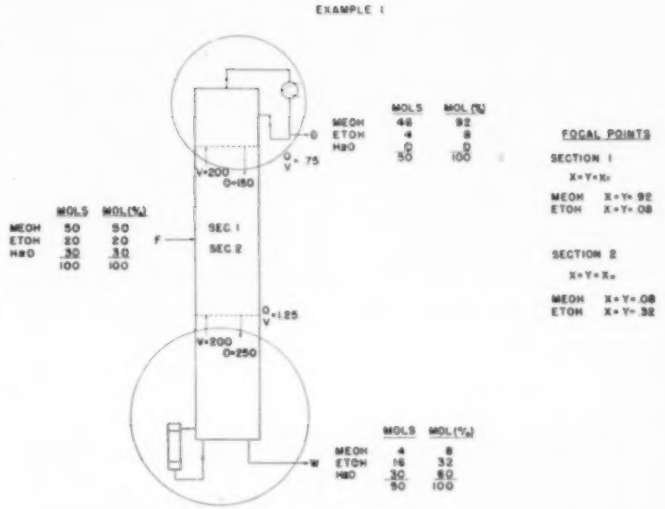
Plot 1 should be mole % A in the liquid vs. mole % A in the vapor at several parameters of constant mole % of B in the liquid to go up a column (or vapor to work down). Plot 2 should be mole % B in the liquid vs. mole % B in the vapor at constant mole % A (liquid or vapor as required). The binary curve for A and B should be on each plot. For extractive distillation, component C is the diluent. Water is usually component C whenever it is present.

† It is possible for the focal point for Section I to be infinite. If $F = D$ it is ∞. This means that it is a 45° line parallel to the $X = Y$ line, and $O/V = 1$ for all plates in that section. In this case, the line would have to be drawn with slope = 1 through the intersection point with the top O/V line for Section II or through the point $Y = Y_A$ in V'.

$$X = \frac{F_1 X_{AF1} + R X_{AR}}{F_1 + R} = X_A$$

of the net flow to the top plate where F_1 and R are all liquid.

EXAMPLE 1



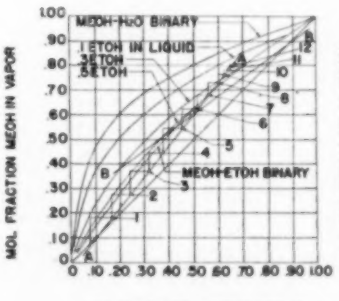


Fig. 1.

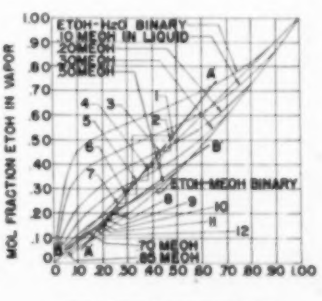


Fig. 2.

Simple Ternary Calculations

Example 1. Data of Griswold and Dinwiddie (*2*) on the system methanol-ethanol-water has been replotted in Figures 1 and 2. Figure 1 is a plot of mole fraction methanol in the liquid vs. mole fraction methanol in the vapor at parameters of constant mole fraction ethanol in the liquid. Figure 2 is a plot of ethanol X vs. Y at parameters of constant mole fraction of methanol in the liquid.

Feeding a mixture of 50 mole % methanol, 20 mole % ethanol and 30 mole % water, it is desired to take an overhead product containing 92 mole % methanol and a bottoms product containing 8 mole % methanol. The column will have two sections and will be operated as shown in Example 1. By material balance calculate the focal points.

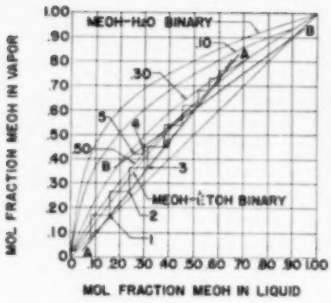


Fig. 1A.

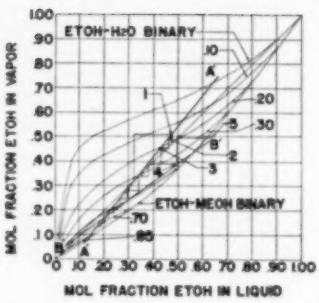


Fig. 2A.

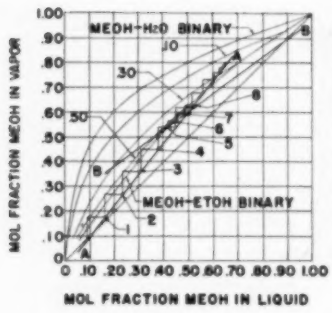


Fig. 1B.

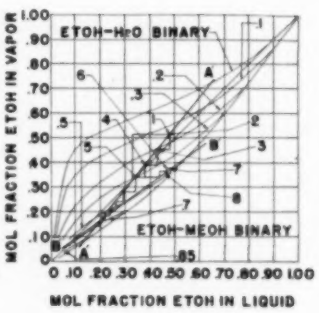


Fig. 2B.

TABLE A.

	Feed = F		Distillate = D		Bottoms = W	
	moles	mole %	moles	mole %	moles	mole %
MEOH	50	50	46	92	4	8
ETOH	20	20	4	8	16	32
H_2O	30	30	..	..	30	60
	100	100	50	100	50	100

200 moles vapor in base.

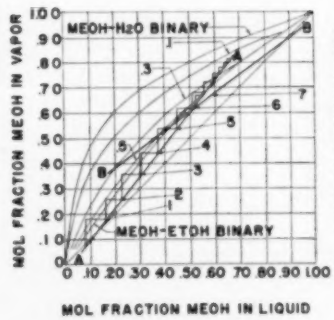


Fig. 1C.

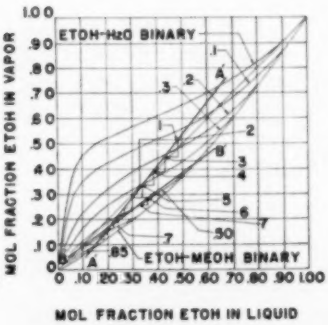


Fig. 2C.

Section I

$$V_{n1-1}Y_{n1-1} = O_{n1}X_{n1} + DX_D$$

$$V_{n1-1} = O_{n1} + D$$

$$X = Y = X_D$$

Section II

$$V_{n2-1}Y_{n2-1} + WX_w = O_{n2}X_{n2}$$

$$V_{n2-1} + W = O_{n2}$$

$$X = Y = X_w$$

Note: For simplicity closed steam has been used. If open steam were used, a steam term would appear in the focal point for Section II as follows:

Section II

$$X = Y = \frac{WX_w - SY_s}{W - S}$$

where S = moles vapor added as steam and Y_s = mole fraction of the particular component in the steam.

Basis: 100 moles of feed.

The material balance is shown in Table A.

Locating the Operating Lines

Neglecting heat effects due to feed conditions, sensible heat, and differing molal latent heats, etc.,

Section II

Focal Points:

$$\text{MEOH}X = Y = .08$$

$$\text{ETOH}X = Y = .32$$

$$O = 200 + 50 = 250$$

$$V = 200$$

$$O/V = \frac{250}{200} = 1.25$$

Section I

Focal Points:

$$\text{MEOH}X = Y = .92$$

$$\text{ETOH}X = Y = .08$$

$$O = 250 - 100 = 150$$

$$V = 200$$

$$O/V = \frac{150}{200} = .75$$

On Figure 1 through $X = Y = .08$ and on Figure 2 through $X = Y = .32$ draw the lines AA and $A'A'$ with slope of 1.25. These will be the operating lines for section II.

On Figure 1 through $X = Y = .92$ and on Figure 2 through $X = Y = .08$ draw lines BB and $B'B'$ with slope of .75. These will be the operating lines for section I. (Note that AA and BB intersect at the $\text{MEOH}X_P$ on Figure 1. The lines $A'A'$ and $B'B'$ intersect on Figure 2 at the $\text{ETOH}X_P$.)

Stepping Off the Plates

Starting at the base of the column step off the plates in the conventional McCabe-Thiele method, making alternate steps on Figures 1 and 2.

For example, the liquid in the reboiler is $X_{\text{MEOH}} = .08$ and $X_{\text{ETOH}} = .32$. On Figure 1 at $X_{\text{MEOH}} = .08$ go vertically to the par-

ameter curve for .32 mole fraction ethanol in the liquid where the Y_{MEOH} from the reboiler is found to be .18 mole fraction. At $Y_{MEOH} = .18$ go horizontally to the line AA where X_{MEOH} plate $1 = .16$. On Figure 2 go vertically at $X_{ETOH} = .32$ to the .08 MEOH parameter curve. The Y_{ETOH} from reboiler is .509. At $Y_{ETOH} = .509$ go horizontally to the line A^1A^1 where the X_{ETOH} on plate 1 is found to be .47.

The composition of the liquid on plate 1 is now known so that as above, the plate 1 vapor composition and the plate 2 liquid composition can be determined by making another step on each diagram. On Figure 1 at $X_{MEOH} = .16$ vertically to the .47 ETOH parameter curve gives Y_{MEOH} from plate $1 = .28$. At $Y_{MEOH} = .28$ horizontally to the line AA gives X_{MEOH} plate $2 = .23$. On Figure 2 at $X_{ETOH} = .47$ go vertically to the .16 MEOH parameter curve. (Note that the point on line A^1A^1 representing the plate 1 ETOH is above the .16 methanol parameter curve and that vertically at $X_{ETOH} = .47$ is down from the line A^1A^1.) The Y_{ETOH} from plate $1 = .505$. At $Y_{ETOH} = .505$ go horizontally (to the left) to the line A^2A^2 where X_{ETOH} plate 2 is found to be .467.

Continue stepping off plates in this manner alternately on Figures 1 and 2. Referring to Figures 1 and 2 it can be seen that on plate 12 the methanol and ethanol have reached pinch concentrations of $X_{MEOH} = .655$ and $X_{ETOH} = .186$.

Also, it can be seen that whenever the line through the focal point for any component lies under the appropriate equilibrium curve, that component will enrich as one goes up the column. As long as the line lies above the appropriate equilibrium curve, that component will diminish as one works up the column.

Introducing the Feed

The feed plate composition must lie on the line with proper slope through the focal point for section II. Compositions on the plate above the feed must lie on the lines BB and $B'B'$ through section I focal points.

When the feed is introduced onto any plate n, go vertically to the appropriate equilibrium curve to locate the feed plate Y's, then complete the steps by going horizontally at the feed plate Y's to the lines BB and $B'B'$ to locate the X's on the plate above the feed plate. Continue stepping off plates along the lines BB and $B'B'$ until the distillate concentrations are reached.

In general, when the pinch concentrations of both components are not reached until after crossing the lines for the next section up the column, the optimum feed plate will be the first plate onto which the feed may be introduced that will not cause the concentration of either component to go in the reverse direction than that desired. In most distillations a safe minimum number of plates in one section of the column will be the first plate onto which the feed may be introduced such that, starting from the plate above the feed, the concentrations of both components are changing in the direction desired. In most cases the true minimum number of plates will be the first plate onto which the feed may be introduced such that the concentrations of both components do not change in the opposite direction than desired. That is, in going up from the plate above the feed, the concentration change of one of the key components is in the desired direction and the other is not.

Refer to Figures 1*A* and 2*A*. If the feed is introduced onto plate 3, plate 4 concentrations will be $X_{MEOH} = .29$ and $X_{ETOH} = .494$. It is obvious that the X_{MEOH} will continue to decrease and X_{ETOH} increase and

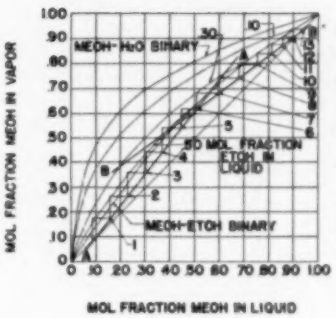


Fig. 1D.

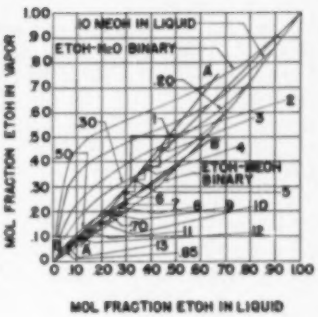
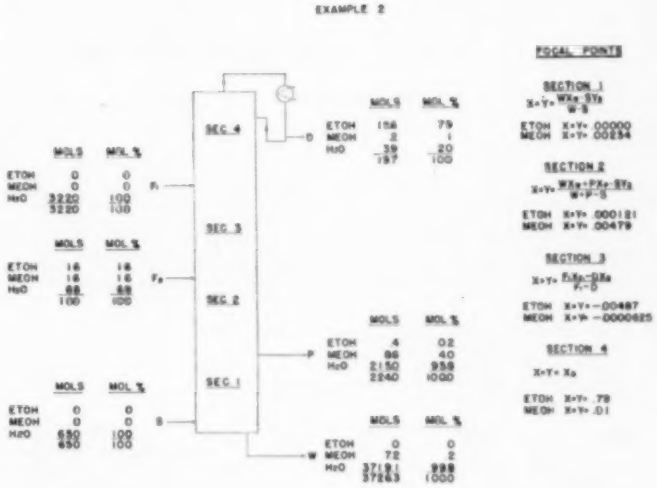


Fig. 2D.



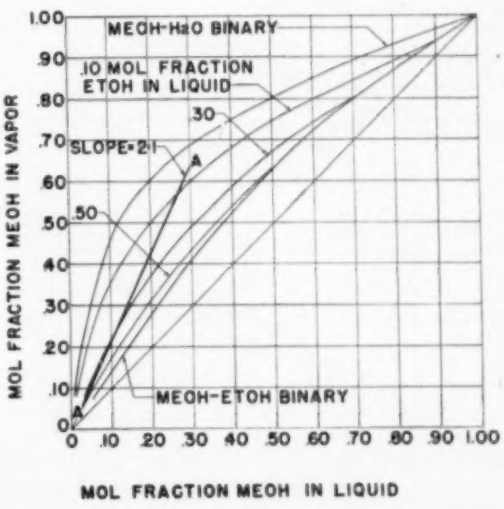


Fig. 3.

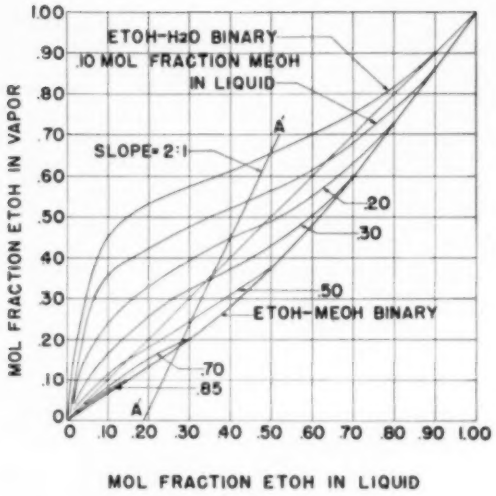


Fig. 4.

that it will be impossible to work up to the distillate composition.

Refer to Figures 1*B* and 2*B*. If the feed is introduced onto plate 4, plate 5 concentrations will be $X_{MEOH} = .415$ and $X_{ETOH} = .42$. The X_{MEOH} enriched but the X_{ETOH} also enriched. Continue stepping off plates along *BB* and *B'B'*. At plate 8 the X_{ETOH} begins to decrease and it will be possible to work up to the proper distillate compositions. The true minimum number of plates for section II at this reflux ratio for this separation would be just under four plates.

If the feed is introduced onto plate 5 (see Figs. 1*C* and 2*C*), it will be seen that the X_{ETOH} increased in going from the feed plate to the plate above, but that starting at plate 6 (the plate above the feed), the concentrations of both MEOH and ETOH are changing in the desired direction. Thus, five plates correspond to the safe minimum number of plates just mentioned.

From inspection of Figure 1 it can be seen that if the feed is introduced on plate 4 or higher, the X_{MEOH} continues to increase.

Stepping Off the Remaining Plates

In Figure 2, plate 6 is the first plate onto which the feed may be introduced and not cause the X_{ETOH} to enrich in going from the feed plate to the plate above. This corresponds to the optimum feed plate for this particular separation.

In Figures 1*D* and 2*D* the feed is introduced onto plate 6 and the remaining plates stepped off. The concentrations on plate 13 would be $X_{MEOH} = .93$ and $X_{ETOH} = .07$, slightly greater than the distillate desired. The column would, therefore, require just under twelve theoretical plates, the distillate being withdrawn from the condenser. (There may be a trace of water in the overhead. Its exact amount would be determined by plotting mole fraction of water in the liquid *vs.* mole fraction in the vapor at constant MEOH in the liquid. The H_2O focal point for Section I could be assumed to be 0. Starting at the concentration on plate 9 and using the concentrations of MEOH previously determined, make four steps to the line with slope = .75 through 0. With the concentration of H_2O found on plate 13, calculate the focal point and draw the section I operation line so that plate 13 concentration falls on the point $X = Y = X_{H_2O}$).

Separation of Methanol and Ethanol by Extractive Distillation

Example 2. Feeding a mixture of 16 mole % methanol, 16 mole % ethanol, and 68 mole % water, it is desired to take ethanol as the overhead product and methanol the bottoms product. This could be done in a simple extraction column consisting of two sections with the extractant, water, being added at the top and flowing out the base. The steam at base of the column will continually strip both the volatile methanol and ethanol from the water

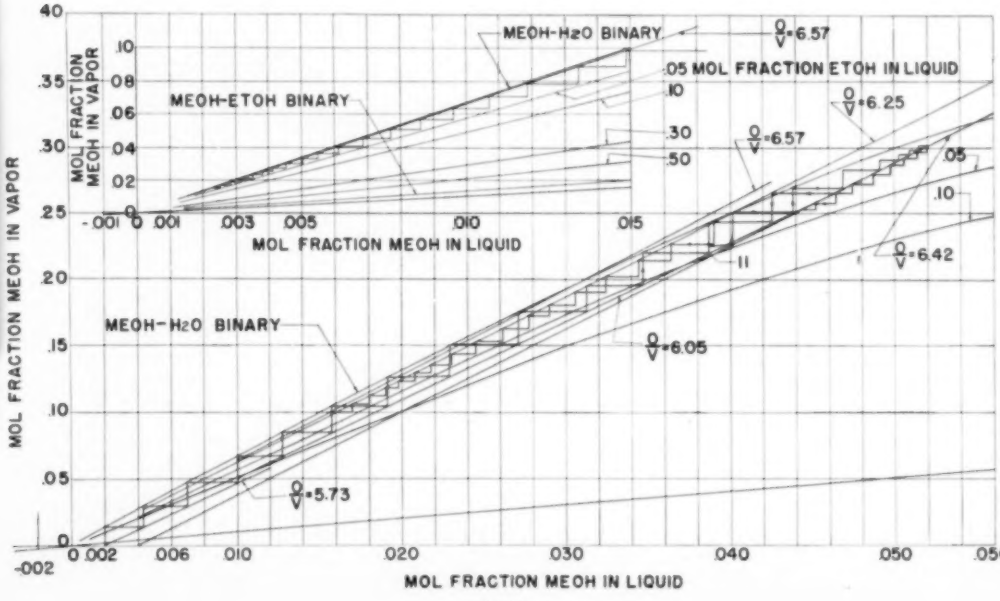


Fig. 3A.

as it flows down the stripping section of the extraction column, however, the water flowing down the dilution section will continually absorb the methanol and return it to the stripping section. This causes the methanol to build up in concentration below the feed plate until it is eventually forced out of the base of the column. The overhead would be a dilute ethanol and would require further rectification. A rectifying section will be added on top of the dilution section of the extraction column to give the final ethanol product desired. The methanol out of the base would be quite dilute and would require considerable steam in the methanol reconcentrating column. For this reason, the methanol will be withdrawn as an enriched side stream a few plates from the base by adding an exhausting section below the stripping section of the extraction column.

Set up the column as shown for Example 2, calculate the focal points for the various sections, and develop the material balance as follows:

To decide on the amount of dilution water at F_1 and steam S to the base, will require manipulating triangles on Figures 3 and 4. The various sections of the column must be inspected on each figure to determine which section and which component is controlling.

On Figure 4 a convenient starting point is section IV. A line tangent to the ETOH-H_2O binary through $x = y = .8$ would be the minimum O/V at the top ($= .50$). For section III the

$$\text{ETOH}x = y = \frac{F_1X_{F_1} - DX_D}{F_1 - D} = \frac{0 - 16}{F_1 - 20}$$

If F_1 is less than 20, $x = y =$ positive and (neglecting heat effects) O/V below

$$F_1 \text{ feed plate} =$$

$$\frac{V + F_1 - D}{V} = 1 + \frac{F_1 - D}{V} = \text{less than 1.}$$

Check this condition on Figure 3. The

$$\text{MEOH}x = y = \frac{-0.1}{F_1 - 20} = .00+.$$

A line through $\text{MEOH}x = y = 0$ with slope less than 1 will give enrichment of MEOH in this section which is contrary to what is required. Thus it can be seen that O/V for section III must be greater than 1, and F_1 greater than D. On Figure 3 the O/V line below F_1 feed plate must lie above the equilibrium curve at the xETOH on F_1 feed plate. On Figure 4 at least a portion of the O/V line through the section III $\text{ETOH}x = y$ must be under the ETOH – H_2O equilibrium curve to enrich ETOH in this section. Furthermore, the xETOH on F_1 feed plate must lie on this line. From the above analysis it is seen that Figure 3 will give the maximum O/V below the F_1 feed plate and Figure 4 will give the minimum O/V below the F_1 feed plate and the limiting $\text{ETOH}x = y$ for section III.

For instance, on Figure 3 the line AA through $\text{MEOH}x = y = 0$ tangent to xETOH = .50 will have a slope = 2.1. On Figure 4 through the point xETOH = .50 on the ETOH – H_2O curve draw the line $A'A'$ with slope = 2.1. Its intersection with the $x = y$ line = .357 (ETOH focal point required for section III). As just shown, the ETOH focal point must be negative for this section. Continuing the above trial on Figures 3 and 4 to 0 mole fraction ETOH, it would still seem impossible. However, on Figure 3A a line tangent to the .05 ETOH curve has a slope of 5.9. On Figure 4A a line through xETOH = .05 with

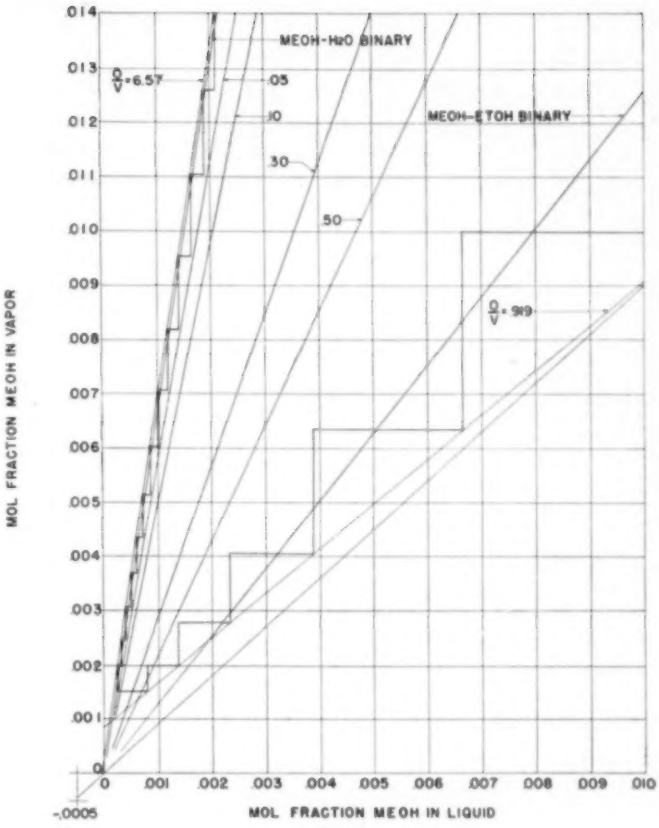


Fig. 3B.

slope = 5.9 gives an ETOH focal point for section III = –.0074. This condition is operable but would require infinite plates to wash out the MEOH. With infinite dilution ($\text{ETOH}x = y = 0$) the maximum xETOH on the F_1 feed plate is about .065. The tangent to the xETOH = .065 curve on Figure 3A is the maximum O/V below F_1 feed plate. On Figure 4 a line through the $\text{ETOH}x = y$ focal point for section III tangent to the ETOH – H_2O binary curve is the minimum O/V below F_1 feed plate.

Set the ETOH focal point for section III $x = y = -.005$ and use an O/V below F_1 feed plate = 6.5.

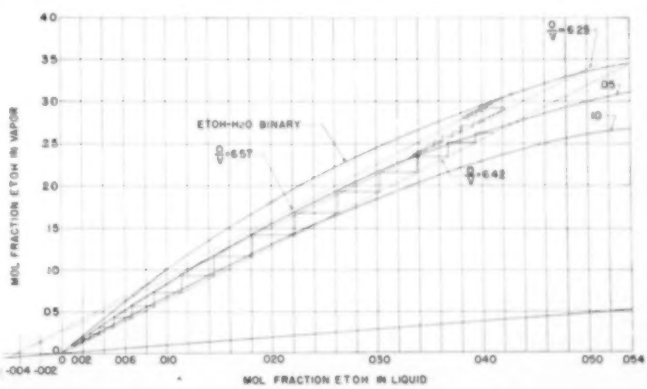
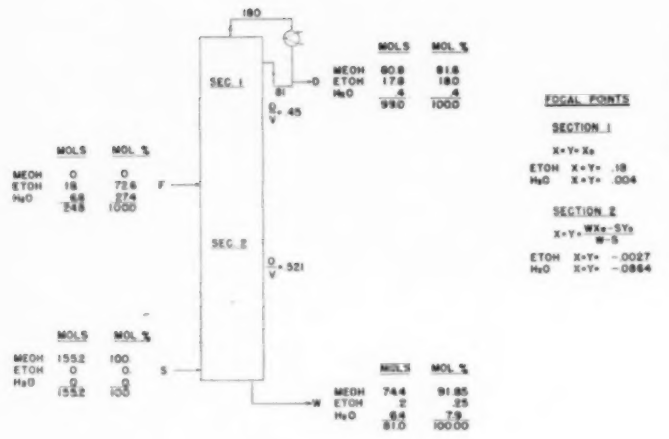


Fig. 4A.

EXAMPLE 3



ETOHx = y =

$$\frac{F_1x_{F1} - Dx_D}{F_1 - D} = -.005 = \frac{0.0 - 16}{F_1 - 20}$$

$$F_1 = 3220 \text{ moles}$$

Now by material balance around circle III

$$V + F_1 = O + D$$

O/V below F_1 feed plate = 6.5; $O = 6.5V$

$$V + 3220 = 6.5V + 20$$

$$V = 581 \text{ to } F_1 \text{ feed plate}$$

$$O = 3781 \text{ from } F_1 \text{ feed plate}$$

At 0% MEOH the xETOH on F_1 feed plate = .043; T = 198° F. yETOH to F_1 feed plate = .308.

Now by approximate heat balance below F_1 feed plate (circle II) determine the amount of steam required at the base.

By material balance in circle II:

$$W + P + V = O + F_2 + S$$

$$W - S = O + F_2 - P - V$$

$$W - S = 3268$$

By Heat Balance:

$$S = 650 \text{ moles.}$$

$$W = 3918 \text{ moles}$$

Calculate the focal points for sections I and II. Determine the O/V for these sections, neglecting heat effects. Now check these conditions on Figures 3 and 4.

Section I.

$$\text{ETOH}x = y = \frac{0+}{3268} = 0.00+$$

$$\text{MEOH}x = y = \frac{.1}{3268} = .0000306$$

$$O/V = \frac{3918}{650} = 6.03$$

Since the side product is withdrawn as a liquid at the temperature of the plate, the xMEOH on the side product plate P will lie on the line through section I focal point with slope of O/V just below side product plate P.

Set the side product concentration to agree with O/V = 6.03 at base.

The line through xMEOH = y = .0000306 with slope = 6.03 intersects the MEOH = H_2O curve at xMEOH = .0475. Due to sensible heat, the side product would have to be less than xMEOH = .0475, but since the amount of water withdrawn at P is increased, the net result will probably allow slightly higher xMEOH in the side stream.

On Figure 4 a line through ETOHx = y = .00+ with slope = 6.03 lies under the xMEOH = .05 curve to xETOH = about .04. This would allow ETOH to enrich in this section as desired.

Section II.

$$\text{ETOH}x = y = \frac{.1}{3300} = .0000303$$

$$\text{MEOH}x = y = \frac{16}{3300} = .00485$$

$$O/V = \frac{3918 + 32}{650} = 6.08$$

On Figure 4A a line with slope = 6.08 intersects the xMEOH = .05 curve at xETOH = .0485. This means that ETOH will enrich to xETOH = .0485 when the xMEOH = .05.

On Figure 3A a line with slope = 6.08 intersects the MEOH − H_2O curve at xMEOH = .0575. It intersects the xETOH = .05 curve at xMEOH = .04. This means that at xETOH = .05, the xMEOH will become .04.

These conditions will be all right for section II.

Now the final material balance is established as shown in Table B.

Focal Point

Section I $x = y = \dfrac{WX_w - Sy_s}{W - S}$

ETOH$x = y$ = 0.00
MEOH$x = y$ = .00234

Section II $x = y =$

$$\frac{WX_w + PX_p - Sy_s}{W + P - S}$$

ETOH$x = y$ = .000121
MEOH$x = y$ = .00479

Section III $x = y = \dfrac{F_1X_{F1} - DX_D}{F_1 - D}$

ETOH$x = y$ = −.00487
MEOH$x = y$ = −.0000625

Section IV $x = y = x_D$

ETOH$x = y$ = .79
MEOH$x = y$ = .01

Section I

$$O/V \text{ at base} = \frac{3726.3}{650} = 5.73$$

On Figure 3A draw the 5.73 O/V line through MEOH$x = y$ = .00234 and step off the plates using the MEOH − H_2O curve to xMEOH = .01.

At xMEOH = .04; T = 200° F. + 7° for column pressure = 207° F. Now by heat balance, determine the vapor below side draw plate P.

$$V = 609$$

$$O = V + W - S = 3685.3$$

$$O/V = 6.05$$

On Figure 3A use O/V = 6.05 to step off plates from xMEOH = .01 to .04. The side product draw-off plate will be the 11½ theoretical plate from the base.

Section II. By material balance at plate P:

$$O_{P-1} = O_P + P = 3685.3 + 224 = 3909.3$$

$$\frac{O_{P-1}}{V_p} = \frac{3909.3}{609} = 6.42$$

On Figure 3A draw a line with slope = 6.42 through MEOH$x = y$ = .00479.

On Figure 4A draw a line with slope = 6.42 through ETOH$x = y$ = .000121.

On Figure 4A start at xETOH = .002 and on Figure 3A start at xMEOH = .04 and step off plates alternately on the two diagrams.

(Note that on Figure 3A the xMEOH soon reaches a maximum at xMEOH = .0520. As xETOH increases, the plate steps will come down beneath the O/V line and xMEOH will decrease. Ultimate pinch concentrations on Figure 3A and Figure 4A

TABLE B.

	F_1 T=182° F.	D T=172° F.		P T=207° F.		W T=220° F.		F_2 T=100° F.	S T=220° F.
	moles	moles	Mole fract.	moles	Mole fract.	moles	Mole fract.	moles	moles
MEOH	16	.20	.01	8.6	.04	7.20	.002	...	...
ETOH	16	15.60	.79	.4	.002	...	...	...	...
H_2O	68	3.90	.20	215.	.958	3719.10	.998	3220	650
		19.7		224.0		3726.3		3220	650

are xMEOH = about .0385 and xETOH = about .0465. Vapor compositions at the pinch are yMEOH = .217 and yETOH = .292.

At xETOH = .0465, T = 197° F. + 5° for column pressure = 202° F.

By heat and material balance calculate the O and V below F_2 feed plate if the pinch concentrations are reached.

$$V \text{ to } F_2 \text{ feed plate} = 614$$
$$O = W + P + V = S = 3914.3$$

Below F_2 feed plate O/V = 6.38. This is close enough to the O/V = 6.46 above side product plate P so that this slight change will be ignored.

Section III. By heat balance, determine the vapor from F_2 feed plate.

$$V \text{ from } F_2 \text{ feed plate} = 610.$$

By material balance O to F_2 feed plate = $F_1 + V = D$ = 3810.3 O/V = 6.25.

On Figure 3A through MEOHx = y = —0.000 and on Figure 4A through ETOHx = y = —.00487 draw lines with slope = 6.25.

In section III the xMEOH should decrease and the xETOH increase as you proceed above the F_2 feed plate. This means that when stepping from the O/V line below the F_2 feed plate to the O/V line above F_2 feed plate the O/V lines for section III should be above the appropriate equilibrium curve on Figure 3A and under on Figure 4A.

On Figure 3A, the xMEOH goes in the desired direction when stepping from section II O/V line to section III O/V line on any plate above plate P. However, on Figure 4A the ninth step is the first and the twelfth step is the last to cross the O/V line through the focal point for section III.

The F_2 feed will be introduced onto plate 23½ or the twelfth plate above plate P.

The F_2 feed plate temperature is about 198° F.+ 5° for column pressure = 203° F. Since this is so close to the previous heat balance and there is only a small concentration change in going to the plate above, the slope of 6.25 should be all right for the plates just above the F_2 feed plate.

At the F_1 feed plate the xMEOH must be very small. The xETOH will equal about .047 and yETOH = .325. T = 197° F. + 2° for column pressure = 199° F.

By heat balance, determine the vapor to the F_1 feed plate.

Moles of V to F_1 feed plate = 574 moles.

By material balance O_{F_1} feed plate = $W + P + V - F_2 - S$.

$$O_{F_1} = 3774.3 \text{ moles}$$

O/V below F_1 feed plate = 6.57

Thus, the O/V changes from 6.25 to 6.57 in going from just above the F_2 feed plate to the F_1 feed plate. This change is due primarily to the decreasing amount of methanol in the vapor.

Use O/V = 6.25 to step off plates until yMEOH = .10, then use O/V = 6.57 to step off the remaining plates to F_1 feed. (Note that the xETOH is continually at the pinch concentration as determined by the xMEOH. As the O/V is changed, the xETOH stays at the pinch concentration.)

Before proceeding too far, locate the O/V line for section IV. By heat balance at F_1 feed plate

V from F_1 feed plate = 240 moles.

O to F_1 feed = $V = D$ = 220.3 moles; O/V = .919

On Figure 3B through $x = y$ = .01 and on Figure 4B through $x = y$ = .79 draw lines with slope = .919. Also on Figures 3B and 4B through $x = y$ = —.0000625 and —.00487 respectively draw lines with slope = 6.57.

Sensible and latent heat effects will be small for section IV and will be ignored.

On Figure 3B it can be seen that the xMEOH must be very small before the F_1 feed is introduced. The xETOH on F_1 feed plate will be its pinch concentration in section III.

Starting at yETOH = .31 as the y_{F_1} feed plate, step off the plates in section IV on Figure 4B to xETOH = .79.

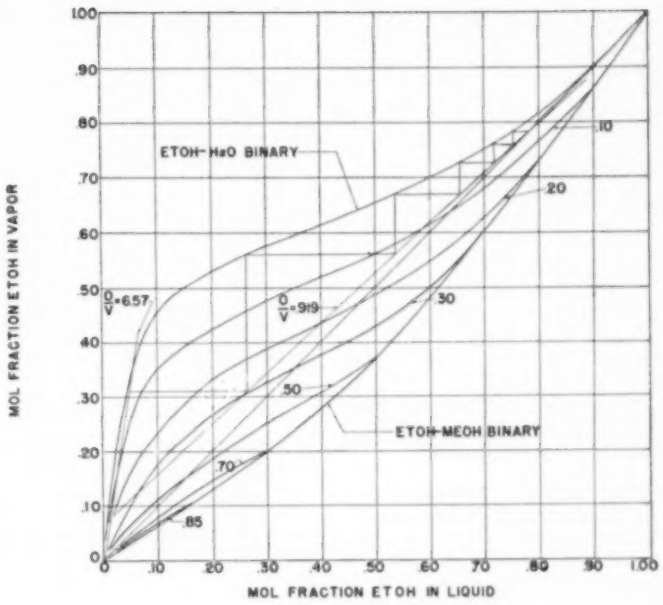


Fig. 4B.

TABLE C.

	F = Feed		D = Distillate		W = Bottoms		S = Vapor to Base	
	moles	mole %	moles	mole %	moles	mole %	moles	mole %
MEOH	0	0	80.8	81.6	74.4	91.85	155.2	100
ETOH	18	72.6	17.8	18.0	.2	.25	0	0
H_2O	6.8	27.4	.4	.4	6.4	7.9	0	0
	24.8	100	99.0	100.	81.0	100.	155.2	100

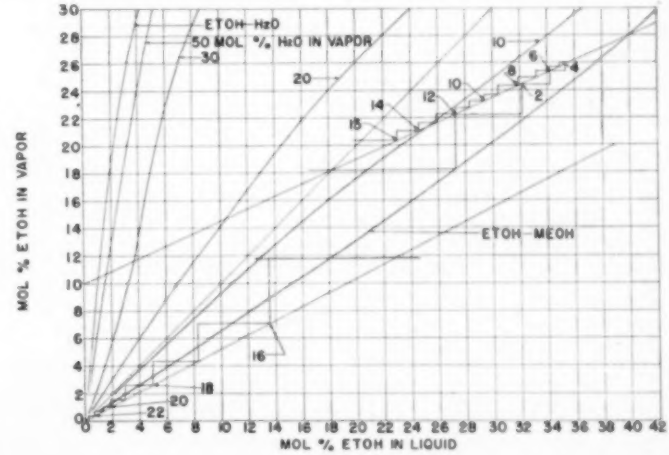


Fig. 5.

Five plates are required in Section IV. On Figure 3*B* at yMEOH = .01 step down five plates to find the yMEOH required above F_1 feed plate. The concentrations of xETOH can be read from Figure 4*B*.

The yMEOH above F_1 feed plate = .001175. xMEOHF_1 feed plate = .000125.

On Figures 3*A* and 3*B* step off the plates required for section III.

Section III requires 47 theoretical plates.

The column required would be as follows:

Section	Theoretical Plates
I	11 ⅓
II	12
III	47
IV	5
	75 ⅓

If the F_1 feed were colder or an internal condenser installed to reduce the vapor to the plate above the feed, the O/V for section IV would be less. This would reduce the number of plates required in section III more than the section IV plates increased and show a net saving of plates.

Dehydration of Ethanol with Methanol by Extractive Distillation

Example III. It will be necessary in this example to determine the plates by starting at the top of the column and working down. To do this, the equilibrium data must be replotted as shown in Figures 5 and 6. Figure 5 is a plot of mole fraction of ethanol in the vapor vs. mole fraction of ethanol in the liquid at parameters of constant mole fraction of water in the vapor. Figure 6 is the y vs. x plot for water at parameters of constant mole fraction of ethanol in the vapor.

The column will be operated as shown in Example III. Methanol vapor will be added at the base of the column. An ethanol-water mixture will be fed to the center of the column as a vapor. A total condenser will be used to condense the vapors out of the top of the column. The condenser effluent will be divided into product which is withdrawn and reflux which is returned to the top plate.

The material balance will be as shown in Table C.

Neglecting heat effects due to sensible heat and differing molal latent heats, calculate the O/V for sections I and II.

Vapor overhead

$$= 155.2 + 24.8 = 180 \text{ moles}$$

$$\text{Reflux} = 180 - 99 = 81$$

$$\text{Section I } O/V = \frac{81}{180} = .45$$

$$\text{Section II } O/V = \frac{81}{155.2} = .521$$

On Figure 5 draw the O/V line for sections I and II through the ethanol focal points. They intersect at the yETOH in the feed. The section II line intersects the x axis properly at x_wETOH. On Figure 6 draw the O/V lines for sections I and II through the water focal points. Their intersection is at $y = .274$ and the section II line intersects the x axis at $x_w H_2O = .079$.

The overhead vapor composition is the same as the product yETOH = .18 and $yH_2O = .004$.

Starting on Figure 5 go horizontally at yETOH = .18 to the equilibrium curve for .004 mole fraction of H_2O in the vapor. This point is xETOH = .27 which is the mole fraction of ETOH in the liquid on the top plate. At xETOH = .27 go vertically to the O/V line. The yETOH = .22 which is the mole fraction of ETOH in the vapor from plate 2.

On Figure 6 make a similar step starting at $yH_2O = .004$. The xH_2O on plate 1 is found to be .017 mole fraction and the yH_2O above plate 2 is .01 mole fraction.

Continue stepping off plates alternately on Figures 5 and 6. Note on Figure 5 that the ETOH nearly reached a pinch concentration on plate 4. If the ETOH focal point is slightly greater, the ETOH would reach a pinch. Also, note Figure 6, that if the ETOH concentration does reach a pinch above about .215 mole fraction in the vapor, the H_2O will also reach a pinch at about .105 to .12 mole fraction in the vapor.

The feed will be introduced just below plate 15 and is assumed to be completely mixed with the vapor leaving plate 16. The yETOH = .202 and the $yH_2O = .12$ in the vapor to plate 15. The total moles of vapor = 180.

By material balance below plate 15

ETOH to plate 15 = .202 × 180 = 36.4 moles
ETOH in feed = .726 × 24.8 = −18

ETOH in vapor from plate 16 = 18.4 moles

H_2O to plate 15 = .12 × 180 = 21.6 moles
H_2O in feed = .274 × 24.8 = 6.8

H_2O in vapor from plate 16 = 14.8 moles

Total vapor to plate 15 = 180 moles
Vapor in feed = 24.8

Total vapor from plate 16 = 155.2 moles

Plate 16

$$\text{yETOH} = \frac{18.4}{155.2} = .1182$$

$$yH_2O = \frac{14.8}{155.2} = .0954$$

Now that the vapor composition above plate 16 is known, start stepping off the plates for section II as at the top of the column, going vertically to the O/V lines for section II.

The bottoms concentrations are reached about 23¼ theoretical plates from the top.

In this column the extractant is added as a vapor at the base. It could be made to look more like the usual extractive distillation column by using methanol as reflux and by taking the total overhead as product. The material balance would have to be adjusted to maintain the same focal points. Maintaining the same reflux ratios would give the same conditions up and down the column except the yETOH in the overhead would be about .10, where the section I line intersects the y axis. The column would require about 1½ more plates in section I.

Setting the bottoms composition to be methanol-water with no ethanol, required in effect turning section II upside down. That is, if any alcohol is in the bottoms, the tendency is for it to be largely ethanol.

If the ethanol focal point in section I is kept at $x = y = .18$, the minimum O/V is about .25; the maximum O/V about .63. The conditions in Section II would, of course, have to be changed as O/V is changed in section I. The maximum concentration of ethanol with no water is about .24 mole fraction.

With the section I conditions existing as in the example just cited, the limits for section II are between an $O/V = .91$ at $x_w H_2O = .17$ to $O/V = .425$ at $x_w H_2O = .03$. The number of plates required will, of course, change, being more at the first condition and less at the latter.

If infinite plates are used in section I, the focal points will shift slightly so that the ethanol will be in a pinch a few plates from the top to the plate above the feed and the water also will be at a pinch above the feed. Infinite plates in section II will cause a slight shift in the focal points so that the ethanol is pinched at the base of the column and the water pinched just below the feed.

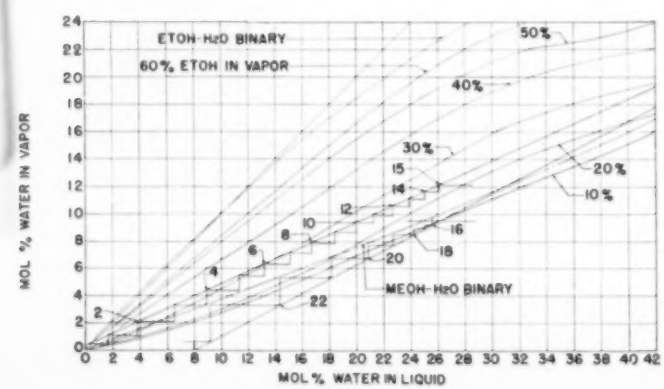


Fig. 6.

With each section at pinch concentrations adjacent to the feed plate, the two sections must match exactly. The plates should be determined by starting at the top and working down for section I and by starting at the base and working up for section II.

Need for Plotting

Once the method of operating a column is decided, the controlling variables may be plotted. This plot will give the entire range and show the optimum reflux ratio to give the minimum plates. Another plot may be made to show the optimum heat consumption. To know what to plot, you first have to know how the column is going to function. The controlling variables will be different for each section and for each type of operation.

In this system, if the O/V in Section I is too high it is impossible to take ethanol overhead without water. As the O/V decreases, the ethanol can be taken overhead without water. Below a minimum O/V it is again impossible to take an anhydrous overhead containing ethanol. Also, unless the conditions for Section I and Section II are carefully set, too many as well as too few theoretical plates in either section will make it impossible to achieve the desired results.

The extractant for extractive distillation may boil higher, lower, or between the components to be separated. It may azeotrope with one or both, as long as the azeotrope formed can be broken or is a product itself, i.e., ethanol-water. Water is an effective extractant for separating most close boiling compounds if their chemical structure is different, even though one or both are only partially miscible. A plot of molecular weight vs. boiling point of the components involved is perhaps the best indication of the suitability of an extractant for a given separation. The suitability of a given extractant may also be determined by the solubility of the compounds to be separated in it, or by the concentrated ratios in a two-phase liquid system.

Preliminary inspection of boiling point vs. molecular weight, solubilities, and concentration ratios in two-phase liquid systems will indicate possible extractant medium for a particular separation. Only actual equilibrium data or a laboratory extractive distillation will prove the extractant's effectiveness.

To design an extractive distillation column plot the equilibrium data in suitable form and decide upon the method of operation. Place the O/V lines to give the desired results and calculate the focal points. Set up the material balance required to give the desired focal points to see if the conditions are possible and accomplish the desired result. For instance, in a given section, the focal point may be negative when O/V is less than 1 and positive when O/V is greater than 1. If the line originally placed is contrary to this, the material balance will indicate the material going in the opposite direction, i.e., you will be adding the pure components and withdrawing a mixture.

Once the limiting relation between O/V and focal points are established, the critical variables may be plotted to show the entire possible operating range, provided, of course, one knows just what the extractive distillation column is trying to do.

Fundamentals Demonstrated by Extractive Distillation

An extractive distillation column has a unique temperature pattern. The temperature usually goes through a minimum between the feed plate and base and goes through a maximum between the feed plate and the top. The temperature at the top is frequently above the temperature at the base and generally the temperature a few plates above the feed is above the base.

The critical O/V for the two sections are entirely unrelated. The possibility of removing or adding heat at the feed plate should always be investigated.

O/V is not the slope of the operating line as normally referred to. Each plate should be considered to have its own operating line; that is, a line through the appropriate focal point with slope equal to the O/V existing immediately below that plate.

The composition of any component in the liquid leaving any particular plate and the composition of the same component in the vapor entering that plate are coordinates of a point on a line through the appropriate focal point with slope of moles of total liquid leaving the plate/moles of total vapor entering the plate.

Latent heat has no temperature level. When more than one component is present, the temperature is determined by equilibrium conditions.

The equilibrium curve is no boundary limiting the concentration changes in a column.

The slope of the so-called q line should be calculated by balance at the feed plate and not be based upon the feed condition.

It is only a coincidence when the concentration ratio of the key components in the liquid on the optimum feed plate is the same as in the feed.

With these fundamentals in mind and properly applied, one can have control of a column even to the point in a binary system of having the less volatile component in the top of the column and the more volatile in thebottom.

Notation

A, B, etc. = component A, B, etc.
D = top product, moles/hr.
F, F_1, F_2 = feed, moles/hr.
P = side stream, moles/hr.
R = reflux from condenser, moles/hr.
S = steam or vapor added into bottom section of column, moles/hr.
W = bottoms, moles/hr.
O = overflow within the column, moles/hr.
V = vapor within the column, moles/hr.
V' = total vapor leaving top of column, moles/hr.
X = liquid composition, mole fraction
Y = vapor composition, mole fraction
n = any plate
n_1, n_2, n_3, etc. = a plate in Section 1, 2, 3, etc., respectively

Acknowledgment

The author wishes to thank W. K. Lewis and G. A. Randall for their critical review prior to publication.

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(Presented at Houston (Tex.) Meeting.)

ERRATA

It has been called to the editor's attention that in the July issue of Chemical Engineering Progress, in the article, "Distillation In 2, 4 and 5.75-inch Diameter Packed Columns," by A. C. Heinlein, R. E. Manning, and M. R. Cannon of Pennsylvania State College, State College, Pa., the decimal points on the various graphs are not clear. In every case the ordinate and abscissa should have decimal points indicated.

The range on the abscissa for Figures 1, 2, 3- for the H.E.T.P. in inches is from 0 to a maximum of 6 in. The pressure drop per plate in inches of water for Figure 4 is from 0 to 0.6; the holdup in gallons per plate for Figure 5 is from 0.01 to 0.10; Figure 6 the holdup in per cent of packed volume is from 10% to 25%; for Figure 7 the liquid velocity in feet per second is 0.017 to 0.037.

For the ordinates, the vapor velocity ranges from 0 through a maximum of 2.2 ft./sec., the maximum being shown in Figure 7.

ELUTRIATION IN A FLUIDIZED BED†

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Narrow cuts of scotchlite bead dust were elutriated from fluidized scotchlite bead beds in a 3-in. diam. laboratory unit. At low initial dust concentrations, the rate data could be represented by a first-order plot, the slope of which was taken as the elutriation rate constant. This rate constant was empirically correlated with the superficial air velocity minus the particle terminal velocity, the bed- and dust-particle diameters, and the depth of bed.

THE elutriation of particles from a fluidized bed is a general problem encountered in applications of the fluidized solids technique. This problem arises out of the fact that the fluidizing gas velocity employed usually exceeds the terminal velocities of the finer particles of the bed, and hence the particles become entrained in the gas, and so are removed. As a consequence, devices such as cyclones and cottrells must be installed in order to separate the entrained solids from the fluidizing gas. It is of practical interest therefore to examine the effect of gas, dust and bed variables on the rate of elutriation.

Early work on the principles of elutriation by Martin (*2*) and Roller (*4*) has shown that the gas velocity required to lift a quartz particle less than a diameter of 70 μ can be predicted from Stokes law. Since dusts lifted from a fluidized solids bed are within this size range, it would be expected that Stokes law would apply, and hence could be used to predict the minimum gas velocity at which a dust particle will be transported from the top surface of the bed. Within the fluidized solids bed, however, as Gilliland (*1*) has pointed out, Stokes law does not apply quantitatively.

The capacity of a fluidized solids bed to retain dust particles at fluidizing gas velocities exceeding the dust-particle terminal velocity has been noted (*1*), but only recently has elutriation rate data become available for the evaluation of dust retention by the bed. Leva (*2*) found that when narrow cuts of fine catalyst dust were added to a coarser-sized catalyst bed, the elutriation rate could be expressed by the law governing first-order chemical reactions. The rate constants were found to be related to the fourth power of the linear gas velocity. Size of coarse and fine constituents, density and bed height were further rate-modifying factors. Experimental data were correlated by an analogy to a modified form of Henry's law.

This paper presents elutriation rate data obtained from experiments with scotchlite bead dusts in scotchlite bead beds. Most data reported here were obtained at dust concentrations lower than normally encountered in most fluidized solids beds operations; nevertheless it is believed that the results are of general interest. The effects of the following variables were examined.

a. Gas velocity, viscosity and density.
b. Initial dust concentration, and dust-particle size.
c. Bed depth and bed-particle size.

† Table 1 in its entirety is on file (Document 3393) with the American Documentation Institute, 1719 N Street, N.W., Washington 6, D. C. Obtainable by remitting $1.00 for microfilm and $1.00 for photocopies.

Fig. 1. Apparatus for elutriation experiments.

Experimental Method

The apparatus is shown schematically in Figure 1. The fludizing unit *E* is a 3-in. diam. column, which was glass in early experiments, then later changed to brass in order to minimize dust holdup on the tube wall caused by electrostatic charges. The grid at the bottom of the tube is a sintered steel plate. The column is about 50 in. high. The collecting assembly *D*, consisting of a cyclone and glass-wool filter, is attached to the top of the column by means of a ball-and-socket joint. The location of *D* was high enough above the bed so that no bed could splash into D, and no further dependence of the elutriation rate on the location of *D* was noted. Air flow rates were obtainable from measurements made with manometer *A* and rotameter *B*. Electrostatic effects were minimized by humidifying the air at *C* to a relative humidity of 60%. In addition column *E* was tapped at frequent intervals during a run to shake down the small amount of dust which adhered to the wall. Electrostatic effects were not completely eliminated but only appeared troublesome at high air velocities, and with the finest dusts.

The bed and dust material consisted of scotchlite glass beads. Scotchlite beads were screened through 80, 100, 150, 200 and 325 Tyler mesh screens, the portions remaining on the 100, 200 and 325 mesh being used as beds. These fractions were blown free of dust in the apparatus at air velocities higher than those used in the elutriation experiments. The material passing the 325-mesh screen was subjected to a sink-float separation using a carbon tetrachloride solution of acetylene tetrabromide of sp. gr.

TABLE 1.—TYPICAL ELUTRIATION DATA WITH AIR

$D \times 10^4$ cm.	l cm.	$d \times 10^4$ cm.	c_o g./100 cm.	v_t^* cm./sec.	v_s cm./sec.	k min.$^{-1}$
145.4	13.9	36.0	0.338	11.9	9.29	0.015
145.4	13.9	25.9	0.301	8.45	4.71	0.043
145.4	13.9	25.9	0.299	11.8	4.71	0.144
145.4	13.9	25.9	0.325	15.3	4.71	0.267
145.4	13.9	17.8	0.272	11.9	2.27	0.456
68.1	13.9	25.9	0.307	12.8	4.71	0.093
58.6	13.9	25.6	0.335	11.6	4.71	0.061
58.6	10.0	25.9	0.072	13.1	4.71	0.190
58.6	10.0	25.9	0.280	13.1	4.71	0.165
58.6	10.0	25.9	0.934	13.1	4.71	0.117
58.6	10.0	25.9	4.63	13.1	4.71	0.033
58.6	14.3	25.9	1.48	13.1	4.71	0.054
58.6	21.4	25.9	1.47	13.1	4.71	0.031
58.6	28.6	25.9	1.48	13.1	4.71	0.019

* v_f at 25° C., 1 atm.

2.3 in order to remove those beads which contained occluded air bubbles. The bottom product was separated by a Haultain Infrasizer into several size fractions. These fractions were used as the dust in the elutriation experiments. An arithmetic average particle diameter was obtained for each dust and bed fraction by microscopic examination of 100 particles. Since scotchlite beads are spherical in shape, there was no need to introduce a shape factor in computing particle diameter. The size distributions of three dust fractions are shown in Figure 2. For convenience, the dust fractions are identified in this paper by the number average diameter.

In each experiment, weighed amounts of dust and bed were thoroughly mixed together and placed in the unit. Initial dust concentrations were varied up to 5% by weight. When the air flow was admitted to the column, elutriation began. At definite time intervals, the cyclone assembly was removed and quickly replaced by another. The cyclone unit was weighed to determine the amount of dust collected. Thus the cumulative weight loss, and the weight of dust remaining in the bed were obtained as a function of time. From 92-98% of the initial dust added was recovered at the completion of a run.

Experimental Observations and Correlations

Data obtained from an elutriation run were plotted as log x/x_o vs. time θ. Typical plots are shown in Figure 3 for data obtained from experiments starting with low initial dust concentrations, i.e., 0.27 to 0.34% by weight. The resulting plots are not truly linear, but are reasonably close to linearity up to 90% dust removal for the 17.8-μ and 25.6-μ dust. In the case of the 36-μ dust there is a curvature toward the time axis throughout. This curvature is believed to be caused by the fact that the dust fraction employed was not homogeneous in size. Since under similar experimental conditions fine dusts elutriate faster than coarse, the finer particles within the size fraction contribute relatively more to the observed rate at the beginning of elutriation than do the coarse. As elutriation proceeds the bed becomes depleted in the finer sizes, and so the rate observed corresponds to the rate for the coarser sizes of dust.

When the initial dust concentrations were higher, the plot log x/x_o vs. θ departed conspicuously from linearity by having a steady curvature away from the time axis. Plots are shown in Figure 4 for initial dust concentrations varying from 0.4 to 5.6%. It is quite evident from these curves that under the experimental conditions employed the initial elutriation rate increased as the dust concentration in the bed decreased.

Based on the approximate linearity of log x/x_o vs. θ which is shown in Figure 3, the elutriation rate constant k was taken as the slope of log x/x_o vs. θ, i.e.,

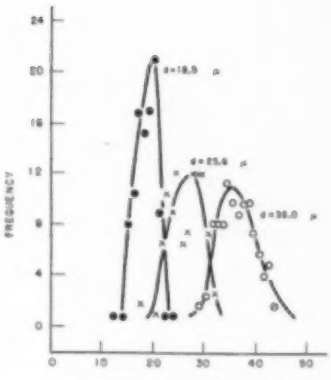

Fig. 2. Size distribution of scotchlite bead dusts.

$$\log x/x_o = -k\theta \qquad (1)$$

For the plots where log x/x_o vs. θ is not even approximately linear, the initial slopes were used in correlations. Basic data used in correlations which follow are listed in Tables 1 and 2.

Effect of Fluidizing Gas Variables. The fluidizing gas in motion provides the "driving force" in elutriation. The

TABLE 2.—ELUTRIATION DATA† FOR CO_2, HE AND FREON 12 AS FLUIDIZING GAS

Gas	c_o g./100 g.	v_t^* cm./sec.	v_s cm./sec.	k min.$^{-1}$
CO_2	0.257	5.17	2.94	0.018
CO_2	0.298	7.33	2.94	0.053
CO_2	0.269	12.5	2.94	0.176
He	0.232	5.10	2.28	0.030
He	0.229	6.90	2.28	0.053
He	0.259	8.46	2.28	0.076
He	0.234	10.2	2.28	0.101
F-12	0.322	5.74	3.54	0.018
F-12	0.314	8.19	3.54	0.085
F-12	0.330	9.91	3.54	0.155

† Bed −200 + 325 mesh scotchlite, depth, 13.9 cm. Dust, 18.5 μ, scotchlite; ρ_s 2.47 g./cc.
* 1 atm. 25° C.

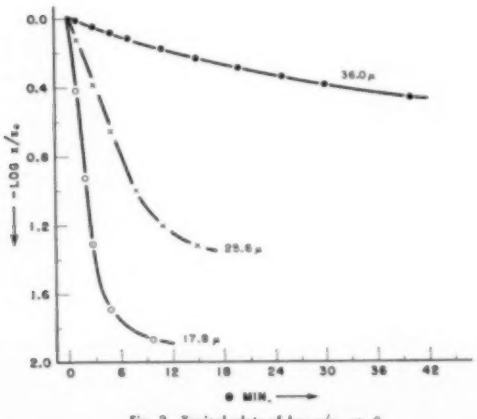

Fig. 3. Typical plots of log x/x_o vs. θ $D = 145.4\mu$, $l = 13.9$ cm., $v_f = 11.9$ cm./sec.

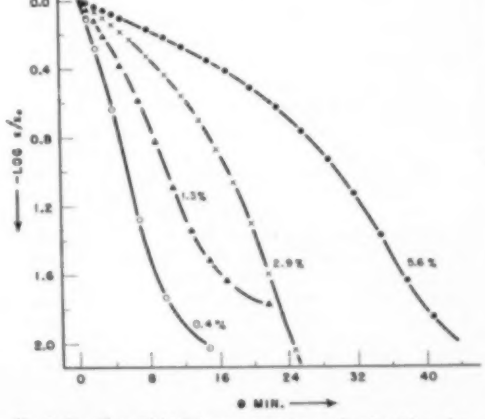

Fig. 4. The effect of initial dust concentration on the plot of log x/x_o against time. $d = 25.6\mu$, $D = 145.4\mu$, $l = 10$ cm., $v_f = 12.4$ cm./sec.

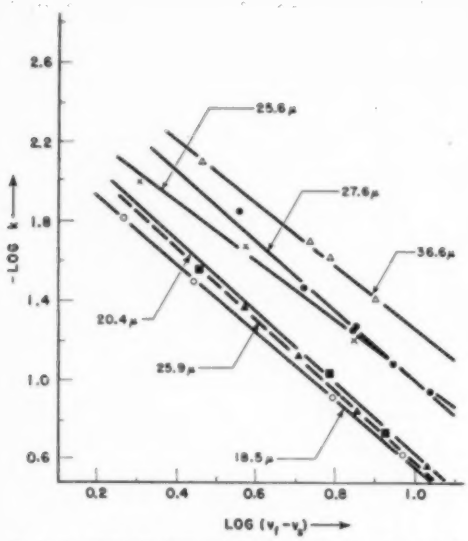

Fig. 5. The relationship between k and $(v_f - v_s)$ using various dust sizes in two different beds.
$D = 58.6\mu$ ——— $D = 145.4\mu$ ——— ———

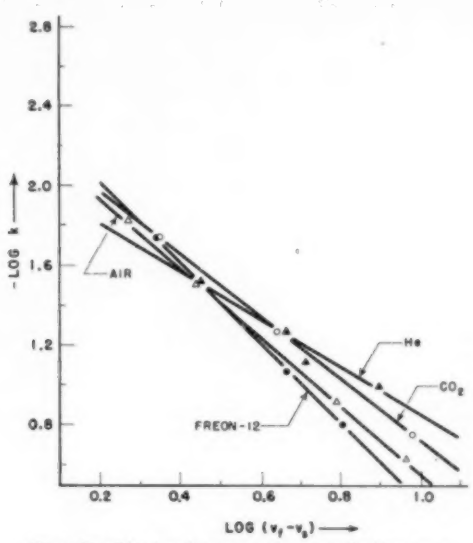

Fig. 6. Plot of log k vs. log $(v_f - v_s)$ for various fluidizing gases.

relationship between gas velocity and rate constant is shown for air in Figure 5 where log k has been plotted against log $(v_f - v_s)$. v_f is the gas velocity computed on the basis of a uniform velocity distribution across an empty tube. This latter assumption is not strictly valid, because visual observations of the suspension in the gas phase during elutriation indicated that the particles in the centre of the gas stream moved faster than particles at the wall. v_s is the terminal velocity of the dust particles calculated from Stokes' law. The term $(v_f - v_s)$ was chosen because of the experimental observation that the elutriation constant is zero when the fluidizing gas velocity in the space above the bed does not exceed the dust particle terminal velocity. The following argument served as a guide.

The mass of dust of diameter d transported from the top surface of the bed is given by:

$$\frac{d(x_o - x)}{d\theta} = nmAv_r \text{ g./sec.} \qquad (2)$$

where nm is the mass of dust of diameter d in the volume flow Av_r. The vertical velocity, v_r, of the dust particle in the free space above the bed can be estimated from a consideration of the forces acting on a particle suspended in the gas stream. The net force F is the sum of the inertia and viscous forces minus the gravitational force, i.e.,

$$F = \pi/4\rho_f v_f^2 d^2 + 3\pi\eta v_f d - \pi/6(\rho_s - \rho_f)gd^3 \qquad (3)$$

In the space above the bed the gas velocities employed were low so that only the viscous force need be considered. If ρ_a instead of $(\rho_s - \rho_f)$ be taken, the vertical velocity v_r of a particle above the bed becomes

$$v_r = \int_{\theta_1}^{\theta_2} \frac{18\eta(v_f - v_s)}{\rho_s d^2}\, d\theta \qquad (4)$$

This integral was not evaluated, but it appeared logical to attempt a correlation of k with $(v_f - v_s)$.

Data are plotted in Figure 5 from a number of experiments where dust size, as well as bed-particle size, has been varied. The lines are approximately parallel, and vary in slope from 1.55 to 1.82. An average value of 1.7 was computed, so that k appears to be proportional to $(v_f - v_s)^{1.7}$. The exponent was found to be independent of the initial dust concentration, at least for the concentration range studied.

When carbon dioxide, helium or Freon 12 were used as the fluidizing gases, different slopes were obtained. In Figure 6 the slope of the log k vs. log $(v_f - v_s)$ is 1.2 for helium, 1.8 for carbon dioxide, and 2.0 for Freon 12. If the same data are plotted as log k against log v_f, a slope of 2.5 for air, 2.5 for carbon dioxide, 1.8 for helium and 4.0 for Freon 12 is obtained.

These results are considered good experimental evidence that the driving force which determines the rate of elutriation is the summation of viscous and inertial forces developed by the turbulent motion of the gas in a fluidized bed. These limited data show that the elutriation constant is affected by both gas density and gas viscosity. The functional relationships were not determined.

Some data for air have been plotted in Figure 7 as $k^{0.6}$ vs. v_f. A straight line drawn through the points is extrapolated to the velocity axis to yield the minimum elutriation velocity. It is evident, too, that the minimum velocity is independent of bed-particle diameter, though k is dependent on bed-particle diameter at other velocities. The Stokes' law terminal velocities are shown in Figure 7 as asterisks, and are compared with the velocity intercepts in Table 3. The agreement between observed and calculated minimum velocities is good, and hence it is concluded that provided the bed is fluidizing the minimum elutriation velocity is largely determined by the experimental conditions existing above the bed.

Effect of Dust Variables. Curves in Figure 4 illustrated the observation that the elutriation rate increased as the concentration of dust in the bed decreased. A series of experiments, in which only the initial concentration of dust was varied, was made, and the initial slopes of log x/x_o vs. θ were determined. These values of k are plotted against the initial concentration c_o in Figure 8. It should be noted that k is approximately inversely proportional to the initial dust concentration in the range one to five per cent, but below about one per cent

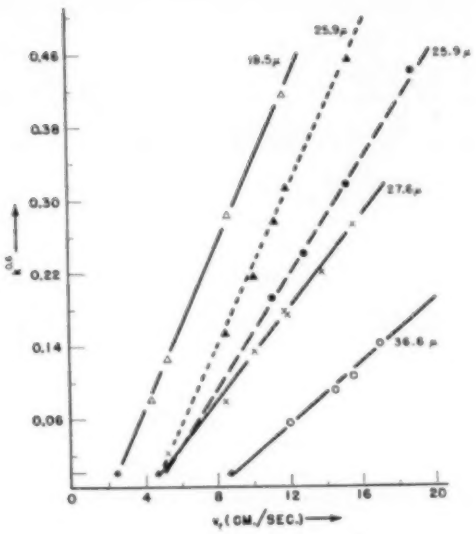

Fig. 7. The relationship between k and the superficial air velocity.
$D = 58.6\mu$ ——
$D = 68.1\mu$ — — —
$D = 145.4\mu$ — — —

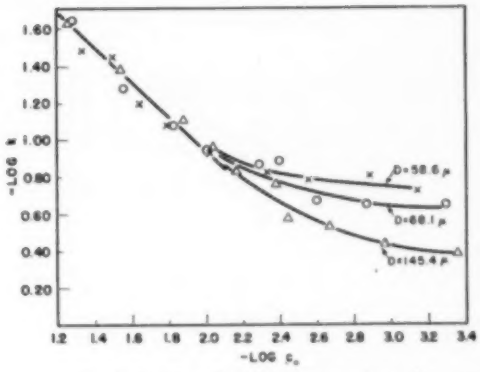

Fig. 8. The effect of initial dust concentration on k.

the dependence on dust concentration decreased and was a function of bed-particle diameter. Leva (*2*) reported that the log x/x_o vs. θ held only over definite concentration ranges, and that beyond a critical concentration referred to as the "break point" the linear relationship no longer held. Our data on log x/x_o vs. θ do not reveal a "break point" but rather a deviation from linearity over the whole concentration range.

The presence of a vertical dust-concentration gradient in the bed was observed. A bed containing a 36-μ dust which was initially distributed uniformly throughout the bed, was fluidized for ten minutes. After stopping the air flow the bed was sampled at different levels. Care was taken to eliminate error to the top sample caused by dust settling back from the space above the bed. Samples were screened, and the resulting data are given in Table 4. The $-150+200$ Tyler mesh bed also contained some $-200+325$ mesh material, and it too segregated at the top. Nine per cent by weight of the $-200+325$ mesh material was found in the top three per cent of the bed. It is believed that segregation of the fines to the top of the bed may account for the observation that the bed-particle diameter has little effect on the elutriation constant, when the dust concentration in the bed is above a certain value. A high-dust concentration at the upper surface of the bed would make the effective bed-particle diameter in this region approach the diameter of the dust particle. No further study was made of segregation, though it is obvious that it is closely associated with the mechanism of elutriation.

TABLE 4.—DUST CONCENTRATION AT DIFFERENT SECTIONS OF A FLUIDIZED BED * AFTER TEN MINUTES OF ELUTRIATION

Bed	Section	Dust Conc %
$-200+325$ mesh	top 6 mm.	2.47
	top quarter	1.71
	2nd quarter	1.79
	3rd quarter	1.75
	bottom quarter	1.68
$-150+200$ mesh	top 6 mm.	3.04
	top quarter	2.00
	2nd quarter	1.99
	3rd quarter	2.07
	bottom quarter	1.87
$-80+100$ mesh	top 6 mm.	2.51
	top quarter	1.98
	2nd quarter	1.88
	3rd quarter	1.71
	bottom quarter	1.47

* Initial over-all dust concentration was 2.17%.
$v_f = 11.9$ cm./sec.
$l = 13.9$ cm.

TABLE 3.—CALCULATED AND EXPERIMENTAL TERMINAL VELOCITIES

Bed Mesh	Dust Micron	Calculated Velocity cm./sec.	Experimental Velocity cm./sec.
$-200+325$	18.5	2.47	2.5
	27.6	4.75	4.9
	36.6	9.06	9.0
$-150+200$	25.9	4.71	5.2
$-80+100$	25.9	4.71	4.9

The effect of dust-particle diameter on the elutriation constant at low-dust concentration was determined by varying the dust-particle size, while the bed-particle size and bed depth were held constant. Initial dust concentrations in the bed were about 0.3% by weight. Data are plotted as log $(v_f - v_o)^{1.7}/k$

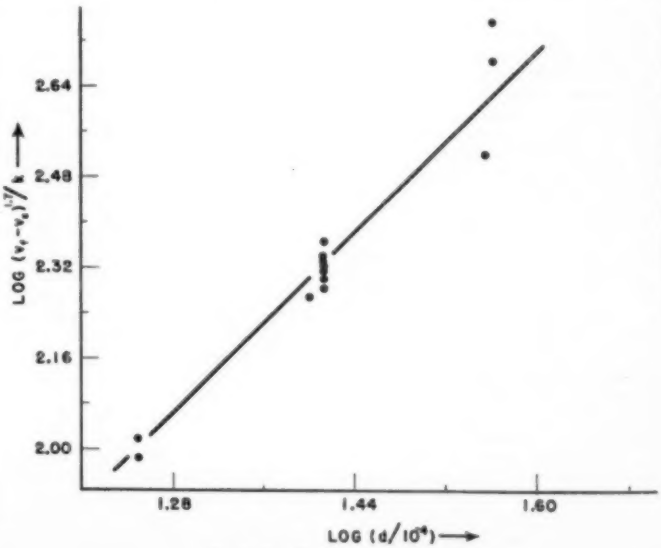

Fig. 9. The effect of dust-particle size.

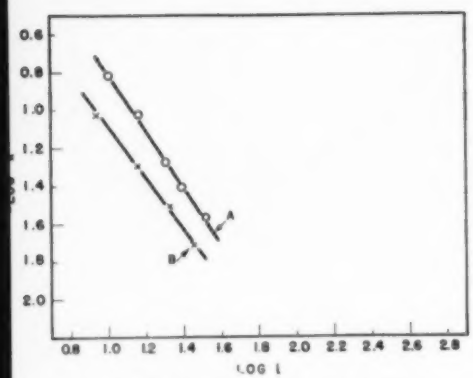

Fig. 10. The relationship between k and bed depth.

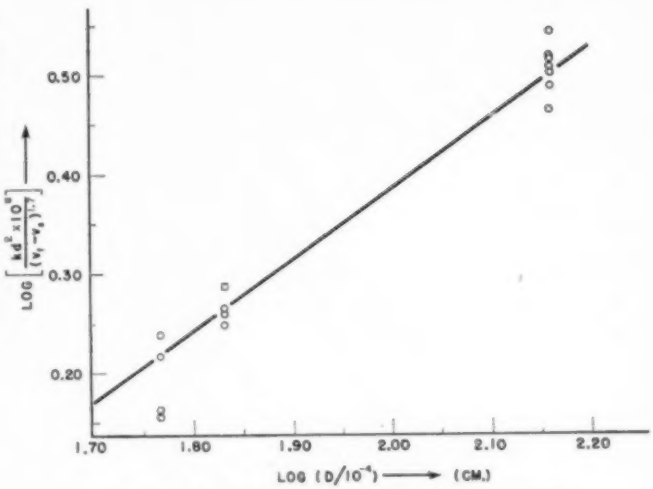

Fig. 11. The effect of bed-particle size at low initial dust concentrations.

vs. log d in Figure 9. A slope of about 2 is obtained, hence the elutriation constant was found to be approximately inversely proportional to d^2.

Microscopic examinations of samples of dust particles collected during elutriation revealed some agglomeration for a 12.5-μ dust fraction. The 18.5-, 25.6- and 36-μ dust fractions elutriated as single particles.

Effect of Bed Variables. The effect of bed depth on elutriation rate is shown in Figure 10 where log k is plotted against log l. l is the depth of the solid bed before fluidization. Two sets of experiments are plotted, curve A for experiments made with an initial dust concentration of 0.47% and curve B for starting dust concentration of 1.47%. The corresponding slopes are 1.48 and 1.36 respectively. These were averaged at 1.4, hence the elutriation constant was found to be inversely proportional to $l^{1.4}$.

Bed-particle diameter appears to have a significant effect on elutriation only at low-dust concentrations. This is illustrated in Figure 8 where the dependence of k on bed-particle diameter appears only at an initial dust concentration of less than about 1% by weight. A series of experiments was made with initial dust concentrations of about 0.3% in which the dust-particle diameter was fixed, but the bed-particle diameter varied. Data are plotted in Figure 11, as log $(kd^2 \times 10^8)/(v_f - v_s)^{1.7}$ against log D. The slope of the line is 0.7, and hence at low-dust concentrations, the elutriation constant varied as $D^{0.7}$. At initial dust concentrations, greater than 1%, the elutriation constant appeared to be independent of bed-particle size. This observation is in agreement with Leva (*2*), who reported no dependence of elutriation constant with bed-particle diameter in the range of dust concentration varying from 20% down to a few per cent by weight.

Summary

The elutriation rate data at low-dust concentrations were satisfactorily plotted as a first-order rate equation.

$$\log x/x_o = -k\theta$$

With air as a fluidizing gas and an initial-dust concentration of about 0.3% by weight of the bed, the elutriation rate constant k was empirically related to the variables studied in the following way:

$$k \propto \frac{(v_f - v_s)^{1.7} D^{0.7}}{d^2 l^{1.4}}$$

At dust concentrations in the bed of less than 1% by weight the dependence of k on the initial dust concentration decreased rapidly, and was found to vary with bed-particle size. Hence, there did not appear to be a simple correlation involving k and dust concentration which would apply irrespective of bed-particle size in this concentration range.

In the range of initial dust concentration of 1 to 5% by weight, it was found that the first-order plot did not strictly apply to the authors' data with scotchlite beads. The initial slope of the plot log x/x_o vs. θ was, however, used, and it was found that the correlation which held at low-dust concentration had to be modified such that k was approximately inversely proportional to the initial dust concentration, and independent of the bed-particle diameter.

Notation

A = cross-sectional area of tube—sq.cm.
c_o = initial dust concentration—g. of dust/100 g. of bed
D = bed-particle diameter, cm. $D = \Sigma ND/\Sigma N$
d = dust-particle diameter, cm. $d = \Sigma Nd/\Sigma N$
F = net force acting on dust particle
g = gravitational constant
k = elutriation rate constant, min.$^{-1}$
l = depth of bed before fluidization—cm.
m = mass of a dust particle of diameter d,—g.
n = number of dust particles per unit volume
v_f = superficial gas velocity—cm./sec.
v_r = vertical velocity of dust particle d, in the free space above bed
v_s = Stokes' law terminal velocity—cm./sec.
x = weight of dust in bed at time θ,—g.
x_o = weight of dust in bed at zero time—g.
η = viscosity of gas—poise
θ = time—minutes
ρ_f = density of fluid—g./cc.
ρ_s = density of dust particle—g./cc.

Acknowledgments

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AN EMPIRICAL EQUATION FOR THERMODYNAMIC PROPERTIES OF LIGHT HYDROCARBONS AND THEIR MIXTURES

REDUCTION OF EQUATION TO CHARTS FOR PREDICTION OF LIQUID-VAPOR EQUILIBRIA

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Equations representing fugacities and liquid-vapor distribution coefficients in mixtures of light hydrocarbons developed in previous papers of this series are reduced to chart form to facilitate engineering application. This has been made possible by the discovery that the effect of composition on fugacities and distribution coefficients can be represented with sufficient accuracy by a single composition variable for each phase, its molal average boiling point.

A set of 324 charts has been prepared for the 12 hydrocarbons

methane	propane	isopentane
ethylene	isobutane	*n*-pentane
ethane	isobutylene	*n*-hexane
propylene	*n*-butane	*n*-heptane

at 26 pressures between 14.7 and 3600 lbs./sq.in.abs. The charts cover a temperature range from −100° to +400° F. and a range of molal average boiling points from −255° to +180° F. At pressures between 14.7 and 1000 lbs./sq.in.abs., the charts represent the dependence of the distribution coefficient, K, on temperature and the molal average boiling point of the vapor and liquid phases. At pressures between 1000 and 3600 lbs./sq.in.abs. the charts represent the dependence of the fugacity:mole fraction ratio (here called fugacity coefficient) on temperature and molal average boiling point.

In 12 mixtures of light hydrocarbons the average deviation of chart K's from those evaluated by the fugacity equations is only 3.2 per cent. This shows that the charts adequately represent the fugacity equations despite the drastic reduction in the number of variables used to represent the effect of composition.

In 27 systems, comprising most of the reported experimental studies of liquid-vapor equilibria in light hydrocarbon mixtures, the average deviation of observed K's from those read from the charts is 7.1 per cent. This shows that the charts may be used for the prediction of dew points, bubble points and equilibrium flash separations with an accuracy sufficient for most engineering purposes. Examples of such calculations are given.

Complete data for Tables 1-4 and 6-8, which accompany this installment of the paper are on file (Document 3359) with the American Documentation Institute, 1719 N Street, Northwest, Washington, D. C. Obtainable by remitting $1.20 for microfilm and $1.00 for photocopies.

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1. Introduction

THE first two papers of this series (*2, 3*) proposed a group of empirical equations for representing the difference between thermodynamic properties of gaseous or liquid mixtures of light hydrocarbons and the properties of the same mixtures in the hypothetical ideal gaseous state at unit pressure. Among the properties represented by these equations are the pressure, enthalpy and entropy of the mixture and the fugacities of the individual components of the mixture. The third paper of this series (*4*) gave constants for these equations for 12 hydrocarbons and showed that thermodynamic properties for the pure hydrocarbons predicted by the equations with these values of the constants were in good agreement with observed properties for these hydrocarbons. The preceding paper of this series (*5*) described the equations for fugacities of individual components in mixtures of light hydrocarbons and showed that liquid-vapor equilibria observed in selected mixtures of light hydrocarbons were in good agreement with equilibria predicted by these fugacity equations.

In principle, then, the problem of predicting liquid-vapor equilibria in any mixture of light hydrocarbons is solved by the development of these equations. In practice, however, use of these equations to compute dew points, bubble points or the composition of coexistent phases involves the tedious solution of a system of involved, nonlinear equations by successive approximations. Although Sage (*14*) has proposed that the solution of these equations be carried out by the new, high-speed electronic

TABLE 5.—FUGACITIES

Molal Average B.P.	System	Mole Fraction Lighter Component	Abs. Pressure lb./sq.in.	Density g. mole/l.	Property Listed	Methane	Ethylene	Ethane
−240° F.	1—6	0.9544	88.8	0.24	f/Py	0.99169	0.97305	0.96646
	1—6	0.9544	203.5	0.56	f/Py	0.98059	0.93847	0.92384
	1—6	0.9544	321.1	0.90	f/Py	0.97000	0.90449	0.88216
	1—5	0.9469	321.4	0.90	f/Py	0.96947	.....	.....
	1—5	0.9469	800.2	2.41	f/Py	0.92756	0.77662	0.74617
	1—5	0.9469	1596.0	4.55	f/Py	0.88517	0.64289	0.57571
	1—5	0.9469	2001.0	6.8	f/Py	0.84277	0.54196	0.46548
	1—6	0.9544	2417.5	8.22	f/Py	0.82107	0.49002	0.41191
	1—7	0.9596	2852.0	9.54	f/Py	0.80225	0.45018	0.37169
	1—7	0.9596	3502.0	11.14	f/Py	0.77985	0.41156	0.33413
−210° F.	1—6	0.8821	98.6	0.27	f/Py	0.9952	0.96726	0.95762
	1—5	0.8625	134.0	0.37	f/Py	1.0007	.....	.....
	1—4	0.8314	299.7	0.86	f/Py	0.9795	0.90226	0.87625
	1—4	0.8314	466.5	1.40	f/Py	0.9701	0.85059	0.81182
	1—3	0.7728	460.4	1.37	f/Py	0.9672	.....	.....
	1—3	0.7728	1000.0	3.44	f/Py	0.9390	0.69973	0.63132
	1—4	0.8314	1602.0	6.36	f/Py	0.9130	0.54808	0.46263
	1—5	0.8625	2480.0	9.66	f/Py	0.8860	0.43756	0.34928
	1—6	0.8821	3092.0	11.05	f/Py	0.8511	0.39566	0.31109
	1—7	0.8955	3750.0	12.17	f/Py	0.8297	0.36896	0.28714
−180° F.	1—5	0.7782	80.0	0.22	f/Py	1.0011	0.97332	0.96378
	1—4	0.7279	217.9	0.63	f/Py	0.9976	0.92660	0.90272
	1—3	0.6333	522.6	1.70	f/Py	0.9944	0.82756	0.77581
	1—3	0.6333	670.1	2.34	f/Py	0.9933	.....	.....
	1—3	0.6333	790.4	2.94	f/Py	1.0064	0.74319	0.66884
	1—2	0.3994	783.7	2.8	f/Py	0.9808	0.74822	0.68051
	1—3	0.6333	1248.0	5.85	f/Py	1.0434	0.60969	0.50870
	1—4	0.7279	1844.0	9.2	f/Py	0.9973	0.48733	0.38167
	1—5	0.7782	2628.0	11.1	f/Py	0.9691	0.40757	0.31149
	1—6	0.8097	3098.0	11.65	f/Py	0.9395	0.38276	0.29150
	1—7	0.8314	3699.0	12.25	f/Py	0.9093	0.36296	0.27532
−150° F.	1—4	0.6245	149.3	0.43	f/Py	1.0108	0.95206	0.93223
	1—3	0.4939	315.5	0.99	f/Py	1.0200	0.89749	0.85802
	1—3	0.4939	490.4	1.74	f/Py	1.0478	0.84277	0.78108
	1—2	0.1710	491.6	1.67	f/Py	1.0151	0.83781	0.78309
	1—2	0.1710	900.3	4.56	f/Py	1.1355	0.70982	0.60488
	1—3	0.4939	1324.0	9.04	f/Py	1.3246	0.58469	0.44989
	1—3	0.4939	1324.0	9.04	f/x	1753.1	773.85	595.44
	1—4	0.6245	1795.0	10.68	f/x	2211.3	882.20	659.93
	1—5	0.6938	2348.0	11.28	f/x	2547.6	1007.6	750.17
	1—6	0.7373	3003.0	11.67	f/x	3148.6	1169.4	871.59
	1—7	0.7673	3644.0	11.97	f/x	3624.0	1343.2	1001.5
−120° F.	1—4	0.5210	104.7	0.30	f/Py	1.0188	0.97068	0.95435
	2—6	0.9734	200.3	0.60	f/Py	1.0178	0.93653	0.90944
	1—3	0.3545	351.4	1.23	f/Py	1.0780	0.90122	0.84665
	1—3	0.3545	498.6	2.16	f/Py	1.1767	0.87165	0.78581
	2—3	0.9102	658.1	3.66	f/Py	1.2783	0.82327	0.70854
	2—3	0.9102	720.0	9.15	f/x	1578.1	656.88	498.09
	2—6	0.9734	741.0	9.40	f/x	1628.5	664.44	501.49
	1—3	0.3545	1112.0	10.49	f/x	2033.7	757.06	556.64
	1—4	0.5210	1610.0	11.10	f/x	2413.7	865.95	629.81
	1—5	0.6095	2053.0	11.17	f/x	2735.7	964.13	703.48
	1—6	0.6650	2801.0	11.33	f/x	3298.7	1147.3	841.95
	1—7	0.7032	3391.0	11.41	f/x	3720.9	1308.6	963.54
−90° F.	1—4	0.4176	86.7	0.25	f/Py	1.0286	0.98267	0.96709
	1—3	0.2151	258.9	0.89	f/Py	1.0959	0.94524	0.89772
	2—3	0.5523	374.2	1.5	f/Py	1.1598	0.94229	0.84990
	2—3	0.5523	528.0	10.97	f/x	2049.3	686.03	492.48
	2—4	0.7634	566.0	11.12	f/x	2096.2	695.91	498.43
	2—7	0.8885	659.0	11.08	f/x	2185.4	716.43	514.09
	1—3	0.2151	810.0	10.80	f/x	2185.2	735.34	527.42
	1—4	0.4176	1360.0	11.00	f/x	2534.1	846.26	604.59
	1—5	0.5252	1756.0	10.86	f/x	2792.6	922.6	667.34
	1—6	0.5926	2480.0	10.83	f/x	3341.4	1105.2	801.90
	1—7	0.6392	3004.0	10.78	f/x	3691.9	1246.2	907.7
	1—7	0.6392	3491.0	10.90	f/x	4023.9	1364.1	998.06
−60° F.	2—5	0.6990	49.8	0.14	f/Py	1.0219	0.9935	0.9839
	2—4	0.5743	124.6	0.38	f/Py	1.0549	0.9817	0.9573
	1—3	0.0757	216.9	0.76	f/Py	1.1238	0.9741	0.9268
	2—3	0.1943	239.8	0.87	f/Py	1.1428	0.9689	0.9235
	2—3	0.1943	282.0	10.74	f/x	2183.7	681.3	480.2
	2—4	0.5743	387.0	10.95	f/x	2287.5	705.6	496.0
	1—3	0.0757	433.0	10.67	f/x	2244.1	704.0	496.7
	2—5	0.6990	495.0	10.94	f/x	2331.1	726.0	511.8

CALCULATED AT 100° F.

Propylene	Propane	Isobutane	Isobutylene	n-Butane	Isopentane	n-Pentane	n-Hexane	n-Heptane
0.95012	0.94692	0.93249	0.93129	0.92712	0.91177	0.90806	0.89077	0.87246
0.8826	0.8754	0.85072	0.84814	0.83938	0.80779	0.80019	0.76561	0.72984
0.82865	0.81801	0.77408	0.77018	0.75762	0.71302	0.70240	0.65495	0.60714
.....	.....	.....	.....	.....	.....	.....	.....	0.61225
0.62340	0.60526	0.52752	0.51991	0.49965	0.43058	0.41515	0.35006	0.29051
0.43754	0.41663	0.33016	0.31978	0.29817	0.23233	0.21811	0.16342	0.11878
0.31955	0.30026	0.22135	0.20947	0.19089	0.13788	0.12638	0.086524	0.056571
0.26828	0.24926	0.17717	0.16474	0.14854	0.10309	0.092944	0.060645	0.037426
0.22975	0.21418	0.14914	0.13559	0.12135	0.082066	0.072991	0.046106	0.027273
0.19794	0.18476	0.12725	0.11270	0.10031	0.067009	0.060289	0.036537	0.020942
0.93219	0.92697	0.90429	0.90271	0.89677	0.87149	0.86485	0.83758	0.8098
.....	.....	.....	.....	.....	.....	.....	.....	0.7565
0.81226	0.79957	0.74555	0.74253	0.72621	0.67400	0.66134	0.60647	0.5528
0.71941	0.70176	0.62815	0.62377	0.60481	0.53516	0.51926	0.45275	0.3910
.....	.....	.....	.....	.....	.....	.....	.....	0.4109
0.48491	0.46030	0.36369	0.35647	0.33349	0.25796	0.24210	0.18141	0.13279
0.29644	0.27307	0.18678	0.17807	0.15996	0.10578	0.095008	0.059669	0.03591
0.19302	0.17557	0.11058	0.099522	0.08568	0.052292	0.044686	0.024782	0.012947
0.16387	0.14921	0.092924	0.080886	0.071054	0.041500	0.034666	0.018620	0.009349
0.14674	0.13418	0.083776	0.070734	0.062158	0.036190	0.029727	0.015788	0.007758
0.93791	0.93176	0.90901	0.90770	0.90182	0.87527	0.87201	0.84004	0.8116
0.84166	0.82903	0.77624	0.77404	0.76065	0.70598	0.69278	0.63812	0.5851
0.65359	0.63032	0.53760	0.53322	0.51092	0.42747	0.40889	0.33584	0.27256
.....	.....	.....	.....	.....	.....	.....	.....	0.17662
0.50579	0.47739	0.36970	0.36376	0.33962	0.25534	0.23769	0.17348	0.12410
0.53155	0.50525	0.40306	0.39760	0.37364	0.29159	0.27461	0.20866	0.15549
0.31542	0.28757	0.18920	0.18139	0.16201	0.10214	0.090714	0.054460	0.031489
0.20028	0.17901	0.10580	0.096800	0.083979	0.047368	0.040376	0.021332	0.010624
0.15072	0.12982	0.077500	0.067143	0.058183	0.031295	0.025509	0.012517	0.005782
0.13798	0.12362	0.071539	0.060309	0.052510	0.027935	0.022272	0.010688	0.004830
0.12858	0.11596	0.067991	0.055758	0.048695	0.026123	0.020493	0.0098068	0.004385
0.87980	0.86859	0.82210	0.82059	0.80909	0.75933	0.74707	0.69716	0.64849
0.75927	0.73921	0.65853	0.65576	0.63639	0.55779	0.53954	0.46724	0.4017
0.63545	0.60767	0.50069	0.49661	0.47226	0.37894	0.35844	0.28187	0.21893
0.55416	0.52932	0.43159	0.42810	0.40492	0.31820	0.29947	0.23502	0.26126
0.39540	0.36254	0.24664	0.24037	0.21704	0.14186	0.12779	0.080286	0.048970
0.22364	0.19685	0.10964	0.10113	0.086826	0.046229	0.038870	0.019320	0.091403
295.99	260.53	145.11	133.85	114.91	61.184	51.445	25.584	12.097
304.29	266.81	143.89	128.03	108.94	55.980	46.116	21.945	10.055
335.53	294.93	159.49	136.26	116.94	58.829	46.605	21.091	8.9932
384.63	340.96	187.43	154.83	134.16	67.234	51.861	22.928	9.664
441.74	395.19	222.32	178.69	155.70	79.448	60.322	26.810	11.256
0.91013	0.90046	0.86043	0.85939	0.84964	0.80606	0.79474	0.75041	0.7069
0.83934	0.82450	0.76376	0.76219	0.74729	0.68475	0.66993	0.60924	0.5515
0.71235	0.68556	0.58177	0.57874	0.55517	0.45957	0.43796	0.35689	0.2882
0.59049	0.55467	0.42382	0.41935	0.39175	0.28786	0.26606	0.19055	0.1344
0.47188	0.42670	0.29704	0.29173	0.26476	0.17371	0.15654	0.099185	0.06135
236.99	206.25	109.61	102.02	86.841	43.973	37.049	17.701	8.092
235.39	204.65	108.03	99.825	84.950	42.556	35.600	16.764	7.562
243.94	210.77	106.98	96.420	81.249	39.552	32.274	14.496	6.182
267.98	232.27	117.87	103.29	86.928	41.670	33.865	15.025	6.251
297.37	258.41	132.81	112.74	96.040	46.125	35.797	15.085	6.112
355.06	312.29	165.00	134.41	116.57	56.048	42.280	17.544	7.047
409.29	363.47	197.37	157.41	136.78	67.302	50.013	20.930	8.415
0.92426	0.91505	0.87569	0.87481	0.86545	0.82213	0.81117	0.76752	0.7245
0.77699	0.75240	0.65476	0.65253	0.63041	0.53670	0.51497	0.43302	0.3616
0.68042	0.64739	0.52361	0.52066	0.49363	0.38681	0.36369	0.28925	0.2127
200.88	171.64	81.877	73.650	61.437	27.979	22.692	9.5822	3.876
201.87	172.51	82.335	73.599	61.389	27.942	22.568	9.4607	3.825
206.44	176.52	84.515	74.107	62.269	27.884	21.927	8.8915	3.493
215.24	184.09	88.170	78.746	65.706	30.089	24.247	10.210	4.107
244.27	210.15	102.06	88.835	74.261	34.478	27.332	11.530	4.587
271.24	235.73	115.62	97.823	82.853	38.509	29.485	11.786	4.591
327.12	285.59	145.74	118.98	102.40	47.669	35.423	13.928	5.394
374.75	330.28	173.41	138.20	119.61	57.139	41.843	16.614	6.436
416.34	370.07	198.24	156.29	136.09	66.138	48.362	19.556	7.703
0.9565	0.9503	0.9249	0.9241	0.9181	0.8853	0.8809	0.8505	0.8204
0.8915	0.8770	0.8186	0.8177	0.8039	0.7415	0.7262	0.6660	0.6088
0.8051	0.7796	0.6806	0.6787	0.6565	0.5601	0.5376	0.4523	0.3800
0.7907	0.7632	0.6571	0.6551	0.6315	0.5304	0.5071	0.4206	0.3141
186.34	157.96	71.98	64.39	53.36	23.290	18.596	7.433	2.8717
190.61	161.88	74.00	65.43	54.25	23.776	18.796	7.503	2.8773
193.41	164.17	75.17	67.05	55.60	24.413	19.459	7.802	3.0033
196.53	166.86	76.66	66.82	55.83	24.225	18.818	7.219	2.7272

TABLE 5.—

Molal Average B.P.	System	Mole Fraction Lighter Component	Abs. Pressure lb./sq.in.	Density g. mole/l.	Property Listed	Methane	Ethylene	Ethane
—60° F.	2—6	0.7616	510.0	10.83	f/x	2429.1	735.6	520.1
	2—7	0.7994	560.0	10.79	f/x	2444.7	745.0	526.5
	1—4	0.3141	1014.0	10.67	f/x	2566.1	812.1	574.5
	1—5	0.4408	1461.0	10.45	f/x	2812.5	894.6	635.4
	1—6	0.5203	2194.0	10.32	f/x	3378.0	1072.3	771.0
	1—7	0.5751	2591.0	10.17	f/x	3618.8	1180.2	851.6
	1—7	0.5751	3508.0	10.34	f/x	4230.8	1395.1	1016.2
—30° F.	1—4	0.2107	61.9	0.18	f/Py	1.0403		
	3—4	0.8167	136.3	0.443	f/Py	1.1009		
	3—4	0.8167	159.4	10.365	f/x	2322.8		
	3—7	0.9458	171.2	10.278	f/x	2328.1		
	2—4	0.3852	260.4	10.520	f/x	2425.5		
	2—7	0.7103	477.7	10.246	f/x	2634.3		
	1—4	0.2107	669.6	10.235	f/x	2584.0		
	1—5	0.3565	1148.5	10.015	f/x	2804.3		
	1—6	0.4479	1770.6	9.790	f/x	3305.1		
	1—7	0.5110	2169.7	9.600	f/x	3590.5		
	1—7	0.5110	2703.9	9.683	f/x	3854.3		
0° F.	3—4	0.4157	73.0	0.22	f/Py	1.0678	1.0126	0.9941
	3—4	0.4157	104.9	9.954	f/x	2467.2	711.2	491.0
	2—4	0.1961	149.3	10.0145	f/x	2517.4	.....	.....
	3—7	0.8272	156.1	9.714	f/x	2494.8	720.0	500.0
	1—4	0.1072	364.1	9.893	f/x	2586.6	754.0	521.1
	2—7	0.6212	411.3	9.654	f/x	2769.6	792.3	552.5
	1—5	0.2721	876.5	9.584	f/x	2790.7	827.1	576.6
	1—6	0.3756	1385.1	9.300	f/x	3237.6	960.9	679.2
	1—7	0.4469	1807.3	9.083	f/x	3435.0	1067.2	753.0
	1—7	0.4469	2700.0	9.195	f/x	3979.7	1243.8	892.9
30° F.	3—4	0.0147	53.7	0.16	f/Py	1.0665		
	1—4	0.0038	52.5	9.50	f/x	2576.5		
	3—4	0.0147	80.2	9.51	f/x	2578.5		
	3—7	0.7085	124.0	9.14	f/x	2617.4		
	2—7	0.5321	344.0	9.08	f/x	2860.5		
	1—5	0.1878	626.0	9.17	f/x	2769.5		
	1—6	0.3032	1053.0	8.85	f/x	3184.8		
	1—7	0.3828	1466.0	8.61	f/x	3348.1		
	1—7	0.3828	2018.0	8.67	f/x	3665.0		
60° F.	4—5	0.5601	25.0	0.071	f/Py	1.0416	1.0189	1.0112
	4—5	0.5601	32.1	8.945	f/x	2648.0	732.8	501.6
	4—7	0.8377	15.0	8.86	f/x	2658.2	.....	.....
	2—5	0.1640	107.0	8.885	f/x	2664.3	742.9	504.7
	2—7	0.4430	284.0	8.547	f/x	2920.3	815.3	565.2
	1—5	0.1035	359.0	8.773	f/x	2725.2	766.3	527.0
	1—6	0.2308	706.0	8.434	f/x	3110.6	875.5	610.9
	1—7	0.3187	1187.0	8.182	f/x	3282.5	970.8	678.8
	1—7	0.3187	1494.0	8.211	f/x	3450.0	1025.3	719.6
90° F.	4—5	0.1035	17.7	0.05	f/Py	1.0405		
	4—5	0.1035	44.0	8.43	f/x	2677.3		
	2—5	0.1035	56.0	8.42	f/x	2755.6		
	4—7	0.6692	59.0	8.29	f/x	2766.1		
	1—5	0.0191	100.5	8.40	f/x	2674.3		
	2—7	0.3539	233.0	8.06	f/x	2957.9		
	1—6	0.1585	547.0	8.06	f/x	3123.0		
	1—7	0.2546	926.0	7.79	f/x	3214.5		
	1—7	0.2546	1543.0	7.84	f/x	3546.7		
120° F.	5—6	0.6062	54.0	7.90	f/x	2808.2	757.4	518.9
	2—6	0.1261	76.0	7.79	f/x	3006.8	.....	.....
	2—7	0.2648	97.0	7.61	f/x	2933.5	809.4	558.7
	1—6	0.0861	335.0	7.71	f/x	3096.0	837.0	578.4
	1—7	0.1905	673.0	7.43	f/x	3141.2	898.0	625.0
	1—7	0.1905	1087.0	7.46	f/x	3354.2	965.7	675.6
150° F.	2—6	0.0202	—13.0	7.39	f/x	2998.3		
	5—6	0.0969	44.0	7.41	f/x	2994.4		
	1—6	0.0138	52.0	7.38	f/x	3023.2		
	2—7	0.1757	67.6	7.21	f/x	2944.5		
	1—7	0.1264	291.0	7.09	f/x	2998.9		
	1—7	0.1264	593.0	7.11	f/x	3146.0		
180° F.	6—7	0.5456	—3.6	6.936	f/x	2968.0		
	4—7	0.1638	22.8	6.888	f/x	2907.9		
	2—7	0.0866	0.4	6.844	f/x	2926.4		
	1—7	0.0623	115.8	6.790	f/x	2951.9		
	1—7	0.0623	283.5	6.800	f/x	3030.5		

—(*Continued*)

Propylene	Propane	Isobutane	Isobutylene	n-Butane	Isopentane	n-Pentane	n-Hexane	n-Heptane
198.64	168.80	77.65	67.05	56.36	24.066	18.434	6.922	2.5794
201.16	171.07	79.04	67.86	57.00	24.441	18.626	6.977	2.5843
232.80	199.39	92.05	77.46	64.42	28.908	22.687	9.175	3.529
251.43	215.24	103.16	87.43	73.72	33.50	25.432	9.751	3.695
307.19	267.02	132.35	108.08	92.80	42.18	31.014	11.672	4.398
343.8	300.87	153.22	122.56	105.69	49.20	35.65	13.508	4.897
419.4	373.2	197.57	154.86	135.08	65.14	47.12	18.526	7.202
								0.7703
								0.5324
								2.4220
								2.3409
								2.4447
								2.1959
								2.8569
								3.0270
								3.515
								4.091
								5.035
0.9424	0.9307	0.8835	0.8829	0.8720	0.8196	0.8063	0.7547	0.7052
180.64	152.46	66.41	58.53	48.24	20.33	15.836	5.956	2.1854
.....	.....	.....	.....	.....	.....	.....	.....	2.1968
184.71	155.83	68.38	59.44	49.40	20.593	15.664	5.625	2.0210
192.62	163.11	71.92	62.80	51.84	22.129	17.150	6.499	2.3868
203.94	172.94	77.38	65.10	54.74	22.78	16.70	5.705	1.9923
219.65	186.09	84.50	72.27	60.45	26.53	19.96	7.136	2.5935
260.58	223.70	100.87	86.51	73.73	32.077	23.291	8.088	2.9055
294.15	254.50	123.07	99.43	85.11	38.120	27.249	9.565	3.428
357.42	314.34	158.01	125.32	108.53	50.379	35.987	13.119	4.873
								0.7592
								2.0391
								2.0628
								1.8348
								1.8686
								2.2751
								2.4841
								2.9274
								3.647
0.9885	0.9833	0.9619	0.9614	0.9565	0.9311	0.9241	0.8978	0.8716
182.34	153.40	65.56	57.13	47.22	19.753	14.976	5.219	1.8472
.....	.....	.....	.....	.....	.....	.....	.....	1.8025
185.66	155.82	66.96	58.22	48.30	20.41	15.34	5.167	1.8184
207.49	175.96	77.62	64.84	54.61	22.625	16.262	5.258	1.7864
194.89	165.03	71.84	62.22	51.71	22.204	16.660	5.652	2.0015
228.57	194.61	87.14	72.84	61.72	26.045	18.786	6.130	2.1304
260.74	224.10	104.24	85.06	72.41	31.293	22.437	7.437	2.5815
278.86	241.04	113.66	92.16	78.78	34.47	24.71	8.303	2.9195
								0.9010
								1.7462
								1.8084
								1.7208
								1.7779
								1.7329
								1.9827
								2.3031
								2.9531
190.67	160.42	68.38	58.96	49.21	20.619	15.182	4.845	1.6691
.....	.....	.....	.....	.....	.....	.....	.....	1.6380
205.08	174.04	75.94	63.41	53.40	22.15	15.85	4.930	1.6322
214.38	182.18	79.41	66.88	56.57	23.535	16.92	5.301	1.8147
235.9	201.55	90.93	74.90	63.50	27.237	19.238	6.096	2.0683
258.2	222.3	102.2	83.48	71.17	31.054	21.939	7.0811	2.4460
								1.5766
								1.6172
								1.6179
								1.6101
								1.7655
								1.9971
								1.5683
								1.5837
								1.5687
								1.6423
								1.7585

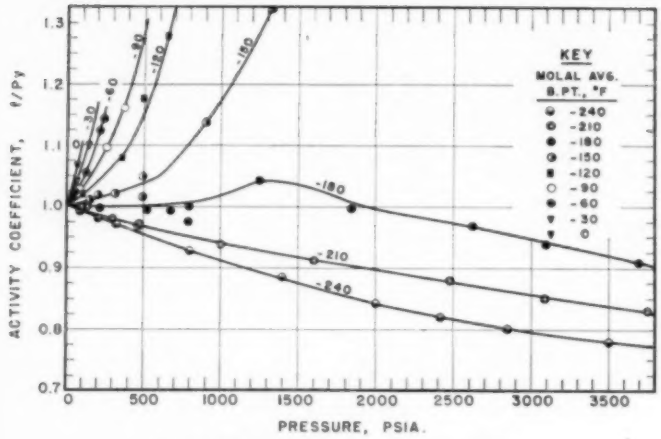

Fig. 1. Activity coefficient of methane in gas phase at 100° F.

computing devices, these aids to calculation will not be available to the average design engineer, and other means to reduce the labor of predicting liquid-vapor equilibrium by these equations will be of value.

The purpose of the present paper is to show how the complex system of fugacity equations may be reduced empirically to a set of charts of fugacity coefficients and K-values that may be used to compute liquid-vapor equilibria in routine design problems without serious loss in accuracy. The procedure for using these charts is described, and an extensive comparison of most of the reported determinations of liquid-vapor equilibria in mixtures of light hydrocarbons with equilibria predicted by the charts is summarized. Although the agreement between the charts and experiment is somewhat poorer than the excellent agreement between the equations and experiment found in the preceding paper (*5*), the correspondence is still close enough to establish the suitability of these fugacity charts in engineering calculations of liquid-vapor equilibria.

Since more than 300 charts, in all, are needed to represent the fugacity coefficients of 12 hydrocarbons in liquid and vapor phases at temperatures from −100° to +400° F. and pressures from 0 to 3600 lb./sq.in.abs., it has not been possible to publish all of these charts in this paper. A complete set of charts, together with detailed directions for their use, may be obtained from the M. W. Kellogg Co. (*19*).

2. Method of Preparing Charts

2.1 Distribution Coefficients (K) and Fugacity Coefficients. In engineering calculations it is customary to express the conditions for equilibrium between liquid and vapor phases in terms of the distribution coefficient, K_i, of each of the components present in both phases. K_i is defined as the ratio of the mole fraction of the ith component in the vapor phase, y_i, to its mole fraction, x_i, in the equilibrium liquid phase:

$$K_i = y_i/x_i \qquad (1)$$

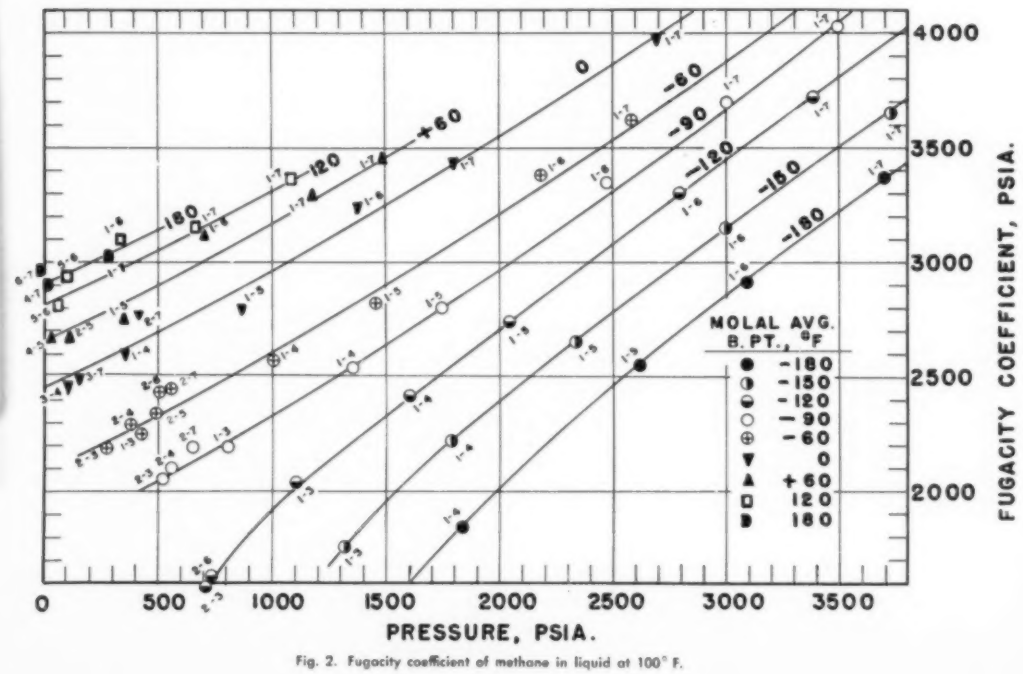

Fig. 2. Fugacity coefficient of methane in liquid at 100° F.

In (5) it was shown that the distribution coefficient of a particular component equals the ratio of the fugacity coefficient of the component in the liquid phase (f_i^L/x_i) to its fugacity coefficient in the vapor phase (f_i^a/y_i):

$$K_i = \frac{(f_i^L/x_i)}{(f_i^a/y_i)} \qquad (2)$$

In this equation f_i^L is the fugacity of the ith component in the liquid phase and f_i^a is its fugacity in the vapor phase.

In the general case, each fugacity coefficient in an r-component mixture is a function of pressure, temperature and $r-1$ composition variables for the appropriate phase. The distribution coefficient, K, is a function of pressure, temperature and all independent composition variables for *both* phases, a total of $2r$ variables. The advantage of expressing K as a ratio of fugacity coefficients is that it permits one to distinguish between the effect of liquid-phase composition on K and the effect of vapor-phase composition.

2.2 Selection of Characterizing Variable. Equations of the preceding paper provide a means for expressing the full dependence of fugacity coefficients in each phase on pressure, temperature and mole fraction. But, as explained above, the equations themselves are too complex for routine engineering calculations, and some means for reducing the equations to graphical or tabular form, to facilitate calculation, is necessary. The most obvious way to do this would be to calculate tables of fugacity coefficients at all pressures, temperatures and compositions of interest. This is completely out of the question for a multicomponent mixture because of the astronomical number of states to be tabulated. For example, if fugacity coefficients were to be tabulated at ten temperatures, 20 pressures and all possible combinations of values of 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0 for the mole fractions of 12 hydrocarbons, a total of 873,600 states would be involved.

At the opposite extreme in tabulating fugacity coefficients or representing them graphically stands the assumption of ideal solutions, the basis for such methods of correlating K's as that of Sherwood (*31*). Under this assumption, fugacity coefficients are completely independent of composition and are functions of pressure and temperature only. In this case it is more convenient to represent K directly, rather than the fugacity coefficient, since K, too, depends only on pressure and temperature. The difficulty with neglecting the effect of composition on fugacity coefficients and K's is that it does not correspond to the experimental facts, particularly at pressure higher than 300 lb./sq.in.abs., and for components above their critical temperatures.

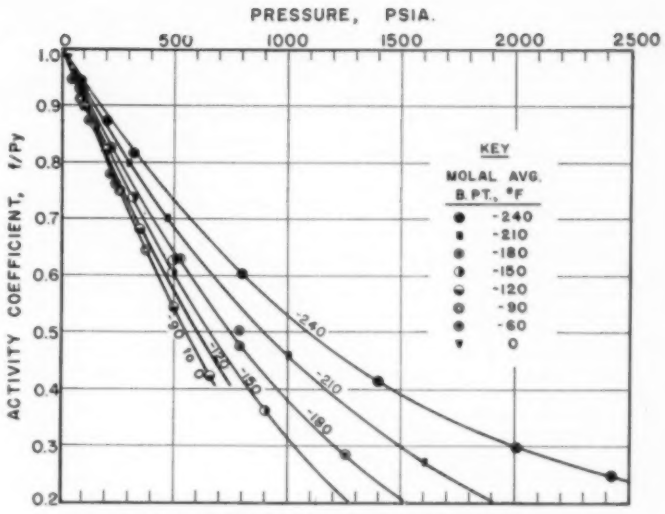

Fig. 3. Activity coefficient of propane in gas phase at 100° F.

Thus, a situation exists in which use of the equations of the preceding paper, involving all composition variables, is accurate, but too complex; and use of the ideal solution assumption, involving no composition variables, is not accurate enough, but is simple. The obvious thing to do is to seek a compromise, in which the fugacity coefficient is represented as a function of a limited number of composition variables, preferably just one, if sufficient accuracy can be obtained thereby. It was found that the molal average boiling point could be used as such a composition-characterizing variable, with but little loss in accuracy. The molal average boiling point, B, is defined as:

$$B = \Sigma_i x_i B_i \qquad (3)$$

where B_i is the normal boiling point of the ith component and x_i is its mole fraction.

The molecular weight was also tried as a characterizing variable, but was

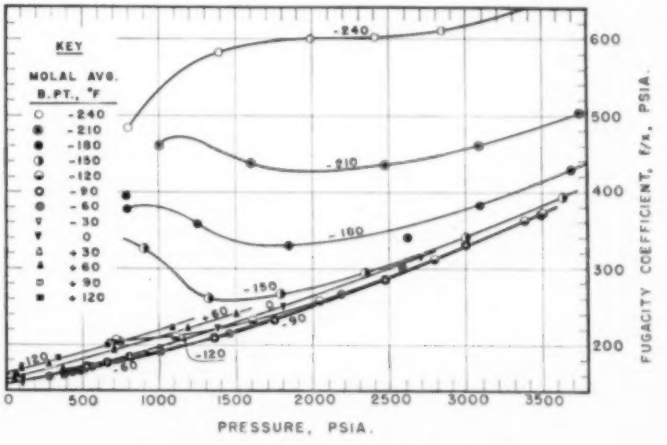

Fig. 4. Fugacity coefficient of propane in liquid at 100° F.

found to be less accurate than the molal average boiling point. This was established by comparing fugacity coefficients calculated by the equations of the preceding paper for a number of states in the methane-ethylene-isobutane and methane - propane - *n* - pentane systems with fugacity coefficients calculated for the binary mixtures of methane-isobutane and methane-*n*-pentane having the same molal average boiling point or the same molecular weight. It was found that the molal average boiling point was the better characterizing variable and that fugacity coefficients calculated by the equation for these three-component mixtures agreed within 5 per cent with fugacity coefficients calculated for two-component mixtures of the same molal average boiling point. An illustration of this point for the system methane-ethylene-isobutane is given in Table 12.†

Because of this encouraging indication it was decided to use these equations to calculate systematically the fugacity coefficients for 12 hydrocarbons as functions of pressure, temperature and molal average boiling point. The 12 hydrocarbons, and the normal boiling point assigned to each, are:

Hydrocarbon	B.P., ° F.	Hydrocarbon	B.P., ° F.
Methane	—258.90	Isobutylene	19.18
Ethylene	—154.66	*n*-Butane	31.10
Ethane	—127.53	Isopentane	82.31
Propylene	—53.79	*n*-Pentane	96.80
Propane	—43.71	*n*-Hexane	155.71
Isobutane	+10.90	*n*-Heptane	209.17

2.3 Selection of States for Computation. After the decision was made to use the molal average boiling point as characterizing variable, it was still necessary to have some rule for selecting from the large number of possible mixtures having even molal average boiling points, a smaller number for which calculation would be practical. The conditions by which these mixtures were selected for computation were:

(1). Only binary mixtures were used.

(2). Binary mixtures were restricted to all possible combinations of the seven normal paraffins between methane and *n*-heptane.

(3). Compositions were chosen to give even values of the molal average boiling point of —255°, —240°, —225°, —210°, —180°, —150°, —120°, —90°, —60°, —30°, 0°, +30°, 60°, 90°, 120°, 150° or 180° F.

Temperatures of —100°, —50°, 0°, 50°, 100°, 200°, 300° and 400° F. were selected for calculation of fugacity coefficients. At each temperature, and for each mixture, the pressures at which fugacity coefficients were calculated were chosen close to the dew and bubble-point pressures of the mixture at that temperature. In this way, the states selected for calculation represent states which could actually be one of a pair in liquid-vapor equilibrium.

At compositions, temperatures and pressures thus selected, fugacity coefficients were calculated by means of the equations of the preceding paper for all 12 hydrocarbons listed above, not only for the two actually present in each binary mixture selected for computation, but also for the remaining 10 hydrocarbons at the limiting concentration of zero mole fraction.

Several exceptions to these rules for selecting states for computation should be mentioned. At —50° F., *n*-hexane and *n*-heptane were omitted from the mixtures used and from the components whose fugacity coefficients were calculated. At —100° F., isopentane, *n*-pentane, *n*-hexane and *n*-heptane were omitted. This was done because K for these components at these low temperatures is so small as to be of little engineering interest. As calculations progressed, it was found that curves of fugacity coefficients against pressure were so regular that some mixtures could be omitted at each temperature.

2.4 Calculated Fugacity Coefficients. Results of these calculations are listed in Tables 1-8,‡ inclusive. Each table refers to a particular temperature and is subdivided according to the molal average boiling point of the mixtures used. Each horizontal row lists fugacity coefficients for a particular state, characterized by the two-component system selected, the mole fraction of light component in the mixture having the requisite molal average boiling point, and the pressure and density at which fugacity coefficients are given. The code used to denote the system used will be clear from an example: 1-4 refers to the methane-*n*-butane system.

To facilitate interpolation in reducing the computed fugacity coefficients to graphical form, it was found convenient to work with the ratio of fugacity coefficient to the pressure, f/Py, in the gas phase. This ratio is dimensionless and is called the "activity coefficient." In Tables 1-8‡ the activity coefficient, f/Py, has been listed for points in the gas phase at low density, and the fugacity coefficient, f/x, has been listed for points in the liquid phase, at higher densities. The fugacity coefficient is in units of pounds per square inch absolute.

These tables provide the raw data from which the finished fugacity coefficient charts were prepared.

2.5 Interpolation to Even Pressures. Since the final charts were to be prepared for even pressures of 14.7, 50, 100, . . . , 3200, 3600 lb./sq.in.abs., the first step in reducing these raw data was to plot f/Py and f/x vs. pressure at constant temperature and constant molal average boiling point and then draw smooth curves through the plotted points. Figures 1-4 illustrate the types of curves obtained for the specific examples of methane and propane at 100° F.

The extent to which the individual points of these figures scatter around the curves drawn through them is an indication of the magnitude of the error introduced in attempting to represent fugacity coefficients in binary mixtures as functions of the molal average boiling point only, disregarding other composition variables. It is seen that the deviations are greater for methane than for propane, but seldom exceed 4 per cent. Figure 2 is keyed to show the binary mixture used at each point.

The main point brought out by these figures is the considerable variation of fugacity coefficients with molal average boiling point at constant temperature and pressure. Similar deviations are found for all components and at all temperatures. The only conditions under which variations in fugacity coefficients with compositions are small enough to be unimportant are (1) in the gas phase for all components at low pressures (e.g., 100 lb./sq.in.abs.) and (2) in either phase for a particular component at molal average boiling points within 50° F. of the boiling point of the component. Thus, K's may be assumed independent of composition in close-cut mixtures whose components boil within 50° F. of one another.

The curves drawn through these plots of fugacity coefficient against pressure were interpolated to even values of the pressure, and the interpolated values were smoothed further by adjusting first and second differences with respect to pressure and molal average boiling point.

As a result of this interpolation and smoothing, tables were prepared giving the activity coefficients and fugacity coefficients of each component at each temperature as a function of pressure and molal average boiling point. Table 9† is an example of such a table for methane at 100° F. Space does not permit publication of the complete set of 90 tables. The final charts are plotted from the data of these tables.

(To be continued)

† See December "C.E.P."

‡ Only Table 5, for 100° F., is published with this paper. The remaining seven tables are on file with the American Documentation Institute.

P-V-T RELATIONS OF GASES

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Experimental compressibility factors of gases may deviate from those predicted by standard compressibility charts. The magnitudes of these deviations are shown to correlate with z_c, the compressibility factor at the critical point for the gas in question. These deviations can be substantial for a gas whose value of z_c differs much from 0.27. A graphical analysis of these deviations is presented, whereby the compressibility factors read from a standard compressibility chart can be corrected.

THE compressibility factor charts, first proposed by Cope, Lewis, and Weber (*10*), are a familiar generalized representation of the pressure-volume-temperature behavior of gases. These charts are constructed on the assumption that z, the compressibility factor, is a unique function of p_r, the reduced pressure, and T_r, the reduced temperature, a relation which can be expressed as follows:

$$z = f(p_r, T_r) \qquad (1)$$

When the compressibility charts first appeared, it was recognized that they represented an excellent first approximation of the behavior of hydrocarbons, but that they were not exact. In other words, contrary to the requirements of this correlation, the compressibility factors for various gases calculated from experimental data at any given p_r and T_r are not identical outside the perfect gas region. Lack of agreement is especially noticeable in the vicinity of the critical, and for substances other than hydrocarbons. This is illustrated by the behavior of z_c, the compressibility factor at the critical point, namely $p_c V_c / RT_c$. Values for z_c of 22 gases, as determined from experimental data, are listed in Table 1, and inspection shows these to vary from 0.305 for hydrogen down to 0.220 for methanol. The compressibility factor charts, on the other hand, would require z_c to have the same value for all these substances.

It seemed likely that the variation of the compressibility factors of gases at any given set of values for p_r and T_r, such as at the critical point, might be related to the variation of these compressibility factors at any other p_r and T_r. A formal expression of such a relation then would be:

$$z = f(p_r, T_r, z_c) \qquad (2)$$

or alternatively, from Equations (1) and (2):

$$z/z_{ref} = f'(p_r, T_r, z_c) \qquad (3)$$

where z is the experimental value of the compressibility factor at the p_r and T_r in question, while z_{ref} is the compressibility factor read directly from a reference compressibility chart at this same point. It is the object here to show the degree of success attained in correlating experimental compressibilities in accordance with relations (2) and (3).

Reference Compressibility Chart. The reference compressibility chart used is presented in Figure 1. The solid lines of this chart, for reduced temperatures of unity and above, are from Su (*45*), and below this temperature are from Seferian (*43*). These solid lines represent average values of compressibilities determined from a number of gases. At reduced pressure and reduced temperature values higher than those covered by these solid lines, experimental data on relatively few gases are available. The dotted lines of Figure 1 were computed from the nitrogen data of Bartlett et al (*2*) and from the ethylene data of Amagat (*1*). The dot-dash lines are from Weber (*47*), Figure 4, page 109, which in turn were computed from hydrogen and helium data using Newton's pseudocritical constants (*30*). These dotted and dot-dash lines are presented in Figure 1 only for general interest, since they fall outside the range of temperature and pressure for which data were available for the construction of the correction charts described here.

Gases Studied. In developing the correction charts proposed below, study was made of compressibility behavior of the 22 gases listed in Table 1, on which reliable *P-V-T* data could be found. The reduced temperatures and pressures explored were limited to the range covered by the solid lines of Figure 1. As mentioned above, this limitation is a consequence of the fact that there are few experimental data for reduced temperatures of 2.0 and higher for gases having a critical ratio under 0.29. Interpolation of these experimental data was often necessary and was accomplished graphically by the usual techniques. For example, constant temperature data were interpolated by plotting the logarithm of the pressure vs. the logarithm of the volume; constant volume data were interpolated by plotting the pressure against the temperature, etc.

Compressibility Factor vs. z_c. The effect of z_c on the compressibility for the gases of Table 1 was tested by plotting z/z_{ref} vs. z_c at various selected values of p_r and T_r. Typical results are shown in Figure 2, where a few of the 1500 data points calculated by Seferian (*43*) are presented. These plotted points are identifiable by Table 1 through the number key at the top of Figure 2. Inspection indicates that a correlation exists between z/z_{ref} and z_c, whose form depends upon the value of p_r and T_r considered. This form changes rapidly near the critical, as is evident from the substantial difference between the lines in Figure 2 at reduced temperatures of 1.0 and 1.05 for a reduced pressure of unity.

Examination of Figure 2 shows that there is some scatter of the points from the average lines, which were drawn by eye. Over the range studied, the greatest deviation encountered was 6%, with most points showing substantially better agreement. It is not clear how much of this scatter is due to inadequacy of the correlation, and how much to error in the experimental data on the *P-V-T* relations or on the critical constants.

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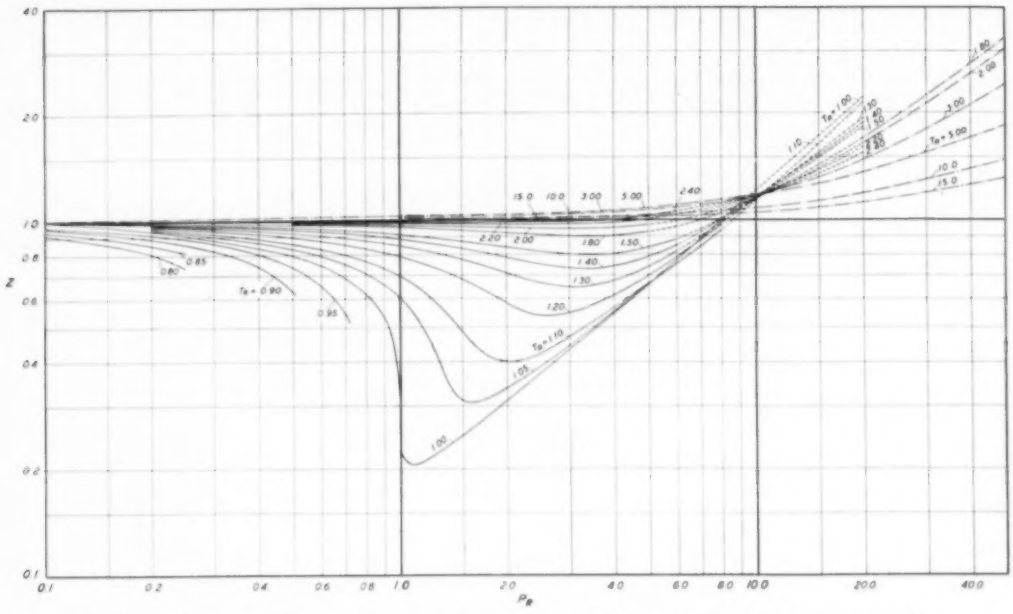

Fig. 1. Generalized compressibility factor chart. The value for the compressibility at the critical point on this chart is 0.27.

Final Correlation. The correlation indicated here could be presented graphically as a series of compressibility charts, one for each value of z_c to be considered, in accordance with Equation (*2*). Alternatively, a compressibility correction chart (i.e., z/z_{ref} vs. p_r for various values of T_r) could be prepared for various values of z_c, as suggested by Equation (*3*). The latter course seemed the simpler, and Figure 3 presents such a group of compressibility correction charts. These were constructed directly from the values read from the lines (not the data points) of Figure *2* and related charts.

TABLE 1

Critical Ratios

	z_c (30, 44)	Source of p-V-T data
1. Methanol	0.220	24, 35
2. Water	.232	17
3. Ammonia	.242	6, 19
4. Ethanol	.248	33
5. n-heptane	.250	44
6. n-hexane	.261	46
7. methyl chloride	.262	22
8. ethyl ether	.262	3, 34
9. n-pentane	.263	36, 38
10. i-pentane	.267	49
11. propane	.270	4, 39, 41
12. dichlorodifluoromethane	.273	9
13. cyclohexane	.274	37
14. benzene	.276 (12)	12
15. n-butane	.277	7, 42
16. ethylene	.279	45
17. carbon dioxide	.280	1, 18, 28
18. ethane	.285	5, 8, 40
19. methane	.289	20, 21, 23
20. nitrogen	.292	2, 13, 32
21. carbon monoxide	.294	2
22. hydrogen	.305	11, 31, 48

The correction charts of Figure 3 are intended for use in conjunction with Figure 1. Strictly speaking, they should not be used with other compressibility charts, such as that presented by Hougen and Watson (*14*). This is because the latter chart differs slightly from Figure 1, since different sets of gases were used as a basis for determining the average compressibilities reported. On the other hand, a given value of z/z_{ref} from Figure 3 could be converted for use with the Hougen and Watson chart by multiplying by the ratio: z (from Fig. 1)/z (from the Hougen and Watson chart), both compressibilities being taken at the T_r and p_r in question.

Critical Constants. Use of the standard compressibility charts requires information on the critical temperature and critical pressure of the substance in question. The correction charts proposed here require additional information for computing z_c, namely the value of the critical volume. There are more data reported in the literature on the critical pressure and critical temperature than on the critical volume, but the latter can be estimated by empirical methods (*26, 27*) when experimental values are lacking.

It should be noted that the hydrogen points were located on Figures 2 and 3 by use of the experimental critical constants, rather than the pseudocritical

constants of Newton (*30*). Therefore, when applying these correction charts, the experimental critical constants should be used throughout, as illustrated below.

Application

a. *Pure Gases.* Use of these compressibility correction charts is best illustrated by two examples:

1. For steam at 5000 lb./sq.in.abs. and 786° F., $p_r = 1.56$ and $T_r = 1.07$ at which condition $z_{ref} = 0.370$ from Figure 1. Figure 3 shows z/z_{ref} at this point to be 0.89 when z_c is 0.23 and 0.99 when z_c is 0.25, hence by linear interpolation, z/z_{ref}

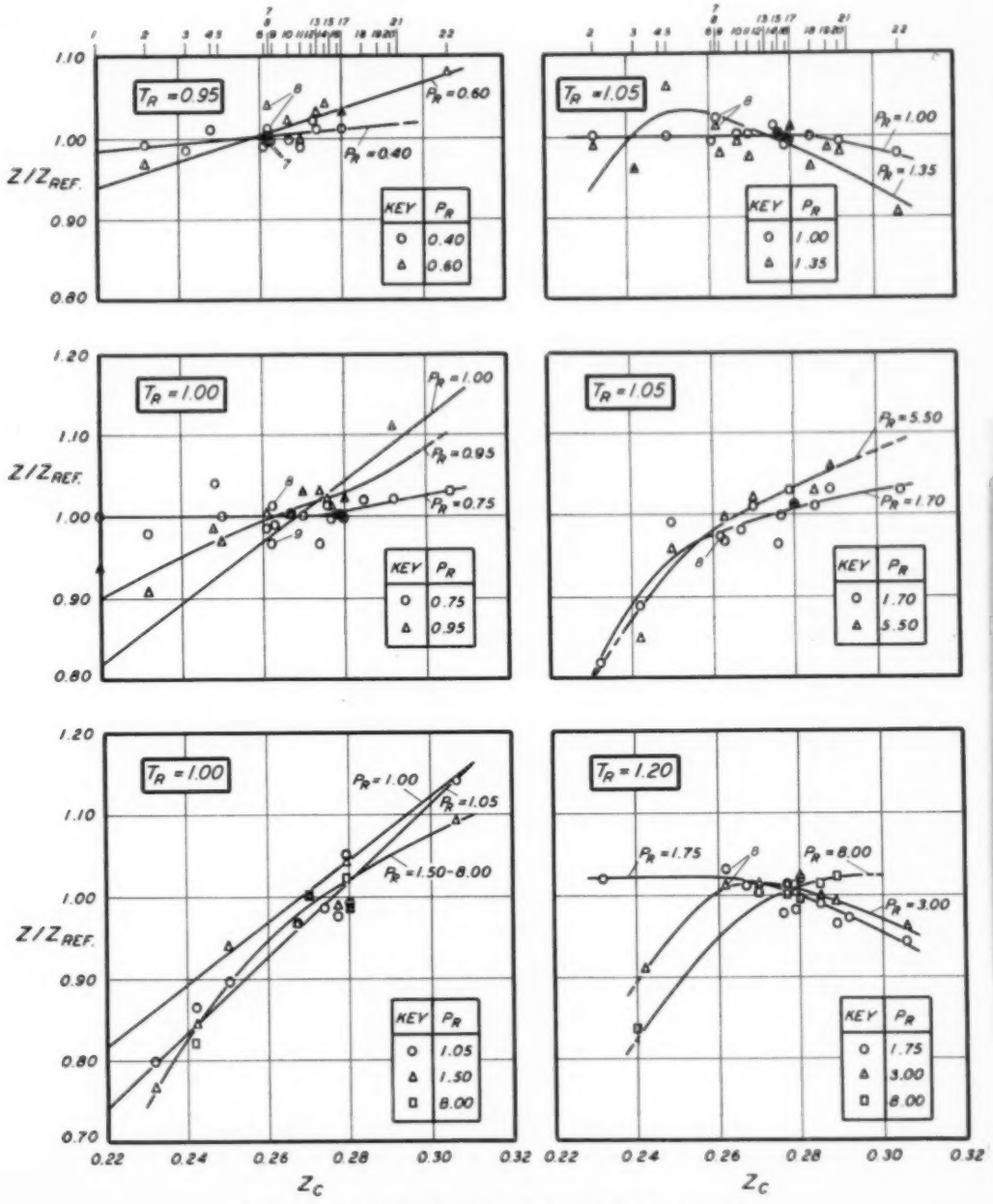

Fig. 2. The ratio (z/z_{ref}) vs. the critical ratio, for selected values of p_r and T_r.

equals 0.90 at steam's value of z_c, namely 0.232. The corrected compressibility for steam is then $0.37 \times 0.90 = 0.33$ and the corresponding specific volume $= zRT/Mp = 0.33 \times 1546 \times 1246/18 \times 144 \times 5000 = 0.049$ cu.ft./lb. This compares favorably with the value of 0.05 from the steam tables (*17*).

2. Hydrogen at 41.69° K. and 34.64 atm. has an experimental value for z of 0.538 (*31*). Using the experimental critical constants, p_c at this point is 2.71, T_r is 1.25, and z_{ref} is 0.60 from Figure 1. From Figure 3, z/z_{ref} is 0.95 at a z_c value of 0.29, and 0.89 at a z_c of 0.31, hence by linear interpolation to hydrogen's z_c of 0.305, z/z_{ref} is 0.92. The corrected compressibility for hydrogen is then $0.6 \times 0.92 = 0.55$, a value which is in reasonable agreement with experiment. It is interesting to note in passing that success is not obtained with Newton's (*30*) pseudocritical constants at this point, since here $p_r^* = 1.675$, $T_r^* = 1.01$, and hence z is 0.28 from Figure 1.

b. *Mixtures.* These charts can be used directly in conjunction with the mixture rules of Amagat, Bartlett, and Dalton, which are discussed, for example, by Weber in Chapter VIII (*47*). On the other hand, some modification is required for Kay's rule (*16*), which states that the pseudocritical constants of a mixture may be computed from the critical constants of the components present, as follows:

$$T_c^*{}_{mix} = T_{c1}x_1 + T_{c2}x_2 + \ldots \quad (4)$$

$$p_c^*{}_{mix} = p_{c1}x_1 + p_{c2}x_2 + \ldots \quad (5)$$

A pseudocritical compressibility for the mixture is presumably to be computed similarly:

$$z_c^*{}_{mix} = z_{c1}x_1 + z_{c2}x_2 + \ldots \quad (6)$$

This extension of Kay's rule unfortunately cannot be adequately tested because the relatively scanty mixture data in the literature happen to involve cases for which z/z_{ref} is always close to unity. In such situations, accuracy is no better than that obtained by use of Kay's rule without the correction charts proposed here, as illustrated by the following example:

A mixture of 59.86 mole % ethylene and 40.14 mole % argon at 120 atm. and 25° C. has a volume of 0.1388 l./mole (*25*). By Equations (4-6), T_r^* is 1.3, p_r^* is 2.42 and z_c^* is 0.28. Figure 1 shows the compressibility to be 0.67, while z/z_{ref} from Figure 3 is 1.01 by interpolation. Using these values the calculated mixture volume is 0.139 l./mole. This excellent agreement with the experimental volume is no satisfactory demonstration of the advantage of Equation (6) since equally good agreement could have been obtained by use of Kay's rule without recourse to the correction factor z/z_{ref}.

Precision. Examination of the proposed correlation shows it to give correct results for pure gases both in the perfect gas or low pressure region, and

TABLE 2

Compressibility Comparison at $T_r = 1.0$, $p_r = 1.2$

From Figure 1, $z_{ref} = 0.71$

	z Experimental	% Error [1]	z/z_ref from Fig. 3	z Calculated 0.71 × z/z_ref	% Error [2]
Water (z_c=.232)	0.17	+24	0.79	.17	0
Ammonia (z_c=0.242)	0.19	+10	0.84	.18	-5
n-heptane (z_c=0.250)	0.20	+ 5	0.89	.19	-5
n-pentane (z_c=0.267)	0.21	0	0.97	.21	0
n-propane (z_c=0.278)	0.21	0	0.97	.21	0
n-butane (z_c=0.277)	0.21	0	1.02	.22	+5
Ethylene (z_c=.279)	0.22	- 5	1.04	.22	0
Carbon dioxide (z_c=0.279)	0.21	0	1.04	.22	+5
Hydrogen (z_c= .305)	0.24	-14	1.13	.24	0
Average error:		±0.56			±2.6

[1] This error = $100(1 - \frac{z_{Experimental}}{0.21})$ where 0.21 is the compressibility from Figure 1 at $p_r = 1.2$ and $T_r = 1.0$.

[2] This error = $100(1 - \frac{z_{Experimental}}{z_{Calculated}})$ where $z_{calc} = 0.21 \times z/z_{ref}$; the latter ratio being obtained from Figure 3, as presented in the preceding two columns of this Table.

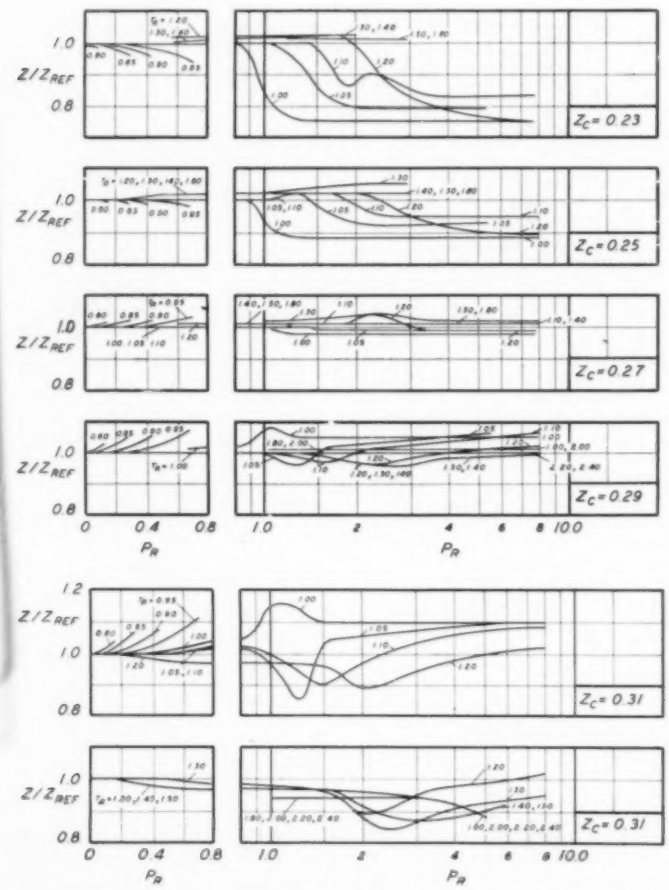

Fig. 3. Correction charts. At each of five different values of z_c, these show the values of (z/z_{ref}) vs. p_r at various constant values of T_r.

also at the critical point. That is, the compressibility becomes unity at low pressures, since here z/z_{ref} (from Fig. 3) and z_{ref} (from Fig. 1) both become unity. At the critical point the correlation is internally consistent in that it correctly shows the compressibility always to become equal to z_c. For example, for a gas having a value of $z_c = 0.31$, Figures 1 and 3 show z_{ref} and z/z_{ref} to be 0.27 and 1.15 respectively at the critical, and so the predicted compressibility becomes $0.27 \times 1.15 = 0.31$.

A typical example of the degree of success encountered by use of Figure 3 is shown in Table 2 which presents the experimental and calculated compressibilities of nine gases at the arbitrarily chosen condition for which p_r is 1.2 and T_r is 1.0. As indicated, the average error in the predicted compressibility here is 6.5% when using the generalized compressibility chart (Fig. 1) as contrasted with 2.2% after using the correction chart (Fig. 3). More significant is the maximum error encountered, which in the former case is 24% compared to 5% in the latter. Further inspection of Table 2 and Figure 3 shows that the correction terms z/z_{ref} are close to unity for gases whose values of z_c range from about 0.25 to 0.28. Clearly, for these gases little improvement can be made by use of correction factors from Figure 3. On the other hand, for gases whose values of z_c lie outside the range of 0.25 to 0.28, this correction term becomes of increasing importance.

This correlation does not apply very well to the rare gases, other than argon.

Comment

The correlation proposed here has been shown to predict the correct compressibilities both in the perfect gas region and at the critical point. As discussed by Joffe (*15*), most other relations fail at one of these two conditions, as for example those of the following types:

$$V_r = f(p_r, T_r) \qquad (7)$$

$$z/z_c = f(p_r, T_r) \qquad (8)$$

The applicability of these two relations at the critical point is clear since they correctly require both V_r and z/z_{ref} to have the single value of unity when p_r and T_r are unity. On the other hand, in the perfect gas region, $pV/RT = 1.0$, and upon dividing by p_cV_c/RT_c:

$$\frac{p_rV_r}{T_r} = \frac{1}{z_c} \qquad (9)$$

If a universal equation of state like Equation (7) existed, then for any given p_r and T_r, the term on the left side of Equation (9) would be identical for all materials in the perfect gas region. This in turn would require the term on the right side of Equation (9), namely z_c, to be identical for all materials, and an inspection of Table 1 shows this to be incorrect. The same kind of difficulty is encountered with Equation (8), which would require the term z/z_c to be identical for all materials at any given p_r and T_r in the perfect gas region. It would follow then that z could not approach unity for all gases at low pressure since z_c is not constant. Thus relations of the form of either Equation (7) or (8) fail in the perfect gas region. It might be noted in passing that Equation (8) is a special (and incorrect) form of the more general Equation (2).

An alternative approach to the improvement of generalized P-V-T relations involves the use of pseudocritical constants, which however again introduce error in the vicinity of the critical. For example, using Newton's (*30*) pseudocriticals for hydrogen, the predicted and experimental compressibilities are respectively 0.27 and 0.63 at the pseudoreduced condition where p_r^* is 1.0 and T_r^* is 1.0. More recently Morgan and Childs (*29*) have proposed an improved method of calculating pseudocritical temperatures and pressures to be used for all gases whose value of z_c lies outside the range of from 0.25 to 0.30. These pseudocriticals are in turn a function of the temperature being considered and are used with compressibility charts like Figure 1 in the usual way. This correlation again does not appear to apply near the critical.

Notation

(Any consistent units)

p = pressure
M = molecular weight
R = ideal gas constant
T = absolute temperature
V = molal volume
x = mole fraction
z = compressibility factor $= pV/RT$

Subscripts

c = critical state
mix = mixture
r = reduced quantity
ref = derived from reference compressibility chart (Fig. 1)
1, 2 = component

Superscripts

* = pseudo

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Discussion

Walter E. Lobo (M. W. Kellogg Co.): The critical temperature and critical pressure you mentioned in Kay's correlation are, I believe, the pseudocritical temperature and pseudocritical pressure and not the actual critical pressure of a mixture. It's purely assumption that the critical ratio of the mixture can be calculated as shown. Also, as you pointed out, there are little real data on the critical ratio. Where one has the critical ratio one usually has the P-V-T data and therefore you don't need the equation. Where you can determine the critical ratio from parachors, you know the compounds you have. Therefore this equation, so far as I can see, is unusable in mixtures where you cannot predict or don't have a means of predicting the critical ratio.

However, I was interested in testing it out. I took your list of compounds and decided to take equal mixtures on a number of them and I had an awful time trying to find a mixture which didn't give me a ratio of z/z_{ref} of about 1. In other words, in nearly every case I happened to pick, the correlation wasn't doing me much good. I finally thought I hit on one, however. I took the ratio of hydrogen to nitrogen for ammonia on which I knew there were some data. I picked the point where there was the largest deviation but when I had finished I found that in order to be in that range the temperature had to be so low that there were no data. Therefore, I haven't been able to prove that the method is an improvement. There is no question but that it predicts the P-V-T data of materials better than the generalized equation but I first would like to find a good method of predicting the critical ratio.

H. P. Meissner: We had equal difficulty in finding a mixture whose pseudocritical compressibility did not give us a value of about .27, where the corrections are practically negligible anyway or which involved pressure and temperature regions into which our correlations do not extend. It would be helpful if more experimental mixture data were available in the literature.

We have not been able to give this relationship an adequate test on mixtures, at least as far as this extended Kay rule technique is concerned.

C. M. Sliepcevich (University of Michigan, Ann Arbor, Mich.): I'm a little bit confused about one of your figures, in which the first equation was that z is a function of p_r and T_r. That is really the modified theorem of corresponding states, isn't it?

H. P. Meissner: Yes, that is the modified form.

C. M. Sliepcevich: And the next form was a function of the reduced pressure, reduced temperature, and the critical ratio. Isn't that then essentially the theorem of corresponding states as it stands?

H. P. Meissner: It's not identical with the original formulation—it's another modification. It is not identical with the formulation which says, for example—the reduced volume shall be a unique function of the reduced pressure and reduced temperature.

C. M. Sliepcevich: In other words, your correlation is materially different from trying to plot $(z\,x)(p_cV_c/RT_c)$ vs. p_r along lines of constant T_r.

H. P. Meissner: It is.

B. W. Gamson (Great Lakes Carbon Corp., Morton Groves, Ill.): I remember a paper several years ago by a man named Morgan from the University of Florida which covered approach of a similar fashion to the one you've outlined. How does your technique compare with his?

H. P. Meissner: I think it was Morgan and Childs who published a paper in which they had a proposal something like this: that for all gases having a critical ratio in excess of a given value one correlation was to be used, while for all materials having a critical ratio smaller than the one proposed, a second correlation was to be used. In other words, the correlation which we have proposed here is not one that was covered by that paper.

Gouq-Jen Su (University of Rochester, Rochester, N. Y.): First, what is your average correction for the z/z_{ref} ratio and the over-all average correction? Second, because the term V_c critical volume is not accurate for most gases I wonder if it is not justified to introduce a further correction factor based upon the V_c term which is not accurate itself?

H. P. Meissner: As far as the average deviation is concerned at the points we have plotted we have made no attempt at an over-all picture. The most serious error encountered from the average lines which we drew through the experimental points was about 6½%. In most cases the deviation of the points from the average lines was smaller than that. Two to three per cent was normally what we ran into. As far as the critical volume is concerned you are perfectly right—an accurate determination of the critical volume experimentally is difficult. The precision of empirical relations for predicting the critical volume is perhaps 4 or 5%, something like that.

Gouq-Jen Su: You say that the average deviation of the z/z_{ref} correctional factor is oftentimes 2% or so. So I would presume from a technical viewpoint it might not be convenient to introduce a third factor which would correct that 2% or 3% deviation from the whole. I mean that if it is a fact that the overall picture of the correction factor so introduced only affects 2% or 3%, it might not be a very practical thing to introduce this third factor.

H. P. Meissner: I think the justification for this sort of treatment of the data lies here: that, as was, of course, evident from the average lines we presented in the first group of figures, the deviation from the compressibility chart especially in the region of the critical temperature could exceed 30% for gases having a high or low value of z_c. On the other hand, the deviation, using the correlations we proposed, was of the smaller magnitude that I indicated just a moment ago. I believe this justifies the introduction of this new correlating factor.

(Presented at Boston Meeting, Swampscott, Mass.)

LETTER TO THE EDITOR

"MATURITY AND RESPONSIBILITY"

Sir:

Thank you very much for printing Mr. Souder's piece. ("C.E.P." August, 1951, p. 383) He goes far beyond what the "do-gooders" and (alleged) intellectuals insist is the All-Inclusive-All of our culture. Mr. Souder's attitude needs to be imitated in large quantities!

I trust you continue to plug away on this thesis, for our present education, somehow or other, gets it across to its charges that the good life consists in assigning responsibility and withholding control.

J. A. Douglas Anniston, Ala.

HYPERSORPTION DESIGN

MODERN ADVANCEMENTS

CLYDE BERG

Union Oil Company of California, Los Angeles, California

THE Hypersorption process currently is carrying out separations on gas streams derived in petroleum refining, chemical manufacture, and natural gas operations. This process has been reviewed in detail in a number of previous papers (*1-5*) and has completed more than four years of commercial operation. Modern advancements in Hypersorption design are outlined which have been incorporated into commercial units with capacities ranging up to 16,000,000 cu.ft./day and abilities to produce as many as four well-fractionated products from a single tower.

Basic Operation. The Hypersorption process employs a moving bed of activated carbon to adsorb and fractionate components of a gas stream. The phenomena of adsorption provide unusual selectivity for the recovery and separation of relatively volatile hydrocarbon gases as well as other components. Activated carbon provides the intense retentive forces necessary for high-efficiency recovery of volatile components, yet unlike other separation media, this high retentive power can be largely released under desorption conditions and stripping effected with ease.

Separations are controlled by conventional temperature controllers actuated by temperature profile, generated as a result of the adsorption effects occurring at various levels in the tower. The process is completely integrated in its operation. Only part-time attention of an operator is normally required, and on stream efficiencies as high as 99 per cent of a year's operation have been set in commercial operations.

Design of Hypersorption Units

A diagram of a Hypersorption unit of modern design is presented in Figure 1. The processing conditions indicated on this diagram are typical of a unit recovering ethylene from a gas produced by high-temperature cracking. It will be noted that in external appearance this unit represents a single, tall fractionating tower, its principal distinctive feature being that of the lift line which is attached to the side of the tower and effects circulation of the solid within the tower by transport as a suspension in a dilute gas stream. The cutaway sections of the diagram reveal the fact that the tower has two heat-exchange sections, a cooler at the top and a Dowtherm-heated stripper exchanger at the bottom. Between the cooler and stripper there are four trays. The feed is introduced through a distribution tray, passes countercurrent to the moving activated carbon and is disengaged as lean overhead product through a tray immediately below the cooling section at the top of the unit. The adsorbed material is produced as two streams; the disengaging tray immediately below the feed point releases the intermediate ethylene product, whereas the disengaging tray near the bottom of the unit just above the stripping section disengages propylene and steam.

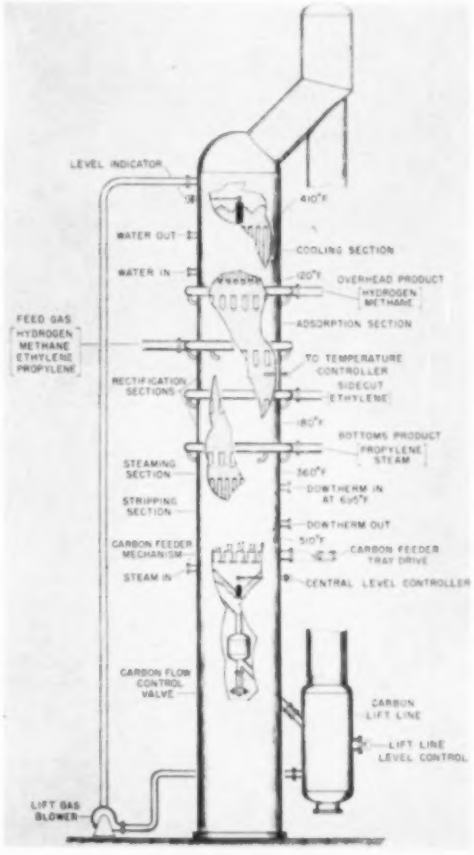

Fig. 1. Hypersorption unit.

Variations in Design for Special Processing Operations

Multiple-Feed Inlet Construction. The general construction of the Hypersorption unit is varied from case to case to suit the processing conditions involved. Figure 2 illustrates the modern construction of the Hypersorption unit for simple top-and-bottom separation. By providing two feed trays in the Hypersorption tower, as illustrated in Figure 3, twice the feed gas throughput capacity can be obtained in a given tower. In this construction each section carries out true countercurrent contact of the feed gas with fresh activated carbon. This is achieved by providing individual delivery of the activated carbon to the top of each bed and regulating the proper withdrawal of activated carbon to the base of each bed by splitters especially designed to give precise proportioning of solids flow in the two beds. The isometric details in Figure 3 show the internals of the tower associated with effecting this distribution of solids flow. Use of multiple-feed trays is not limited to two; as many trays as processing conditions dictate can be incorporated. This use of multiple-feed trays increases the capacity of the unit approximately directly as the number of such trays and is particularly useful in such cases as processing of lean natural gas, propane recovery, and the processing of coke oven gas for ethylene recovery.

Side-Cut Construction. Frequently in processing a separation operation, there is a requirement to produce three product streams. This is effected by withdrawal of the side-cut product. If construction such as illustrated in Figure 1 is employed, this product will be well fractionated as to the separation between the top product and the side cut but will contain some contamination of components present in the bottom stream. A well-fractionated side cut can be produced when conditions dictate, and this is effected by refractionation of the side-cut stream by countercurent contact with a bed of uncontaminated activated carbon delivered directly from the top of the unit. Figure 4 presents construction of this type of unit. Internal delivery of a separate stream of activated carbon is provided to the section effecting final purification of the side cut. The proper location of solids splitting trays results in a precise distribution of the flow of activated carbon between the side-cut rectifying section and the other beds carrying out adsorption, rectification and stripping. Construction of this type is found to be particularly useful in applications, such as production of ethylene streams of low C_3 content, which is frequently dictated by requirements in chemical production. Similar applications for the production of pure acetylene streams exist; generally, the design is applicable in processing operations where specifications and purity of the side-cut stream are of importance.

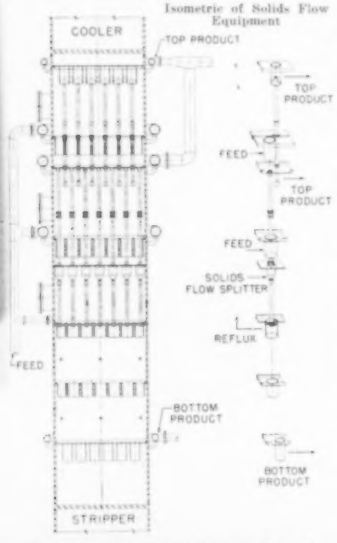

Fig. 3. Double feed tray Hypersorption unit. Internal construction details.

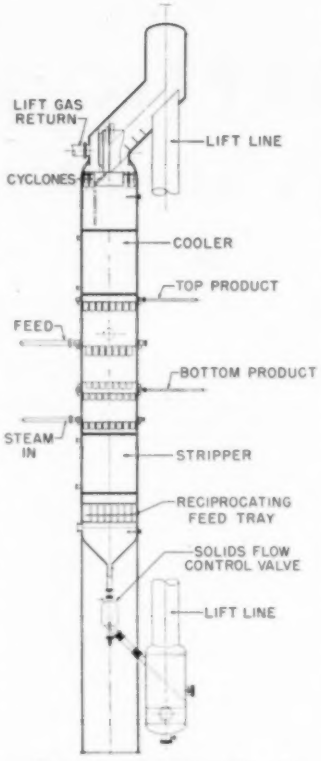

Fig. 2. Two-product Hypersorption unit.

Four-Product Construction. Construction of the Hypersorption unit may be modified to produce four well-fractionated products in a single tower. Figure 5 presents construction of this type of Hypersorption unit. In this construction two separate fractionating sections exist within the tower. Each section effects precise separation into well-fractionated streams, leading to total production of four products, the specifications of which can be adjusted to meet processing requirements. Internal splitter construction adjusts the relative proportion of fresh activated carbon to the several fractionating sections and both streams of activated carbon combine at the base of the unit for a common stripping operation.

The four-product construction has unusual flexibility and finds application in operations such as the handling of refinery gas streams wherein a first side cut of well-fractionated ethylene can be produced, a second side cut of propane and propylene can be produced (meeting *LPG* specifications), and a bottoms product of butane can be produced for gasoline blending. Other applications in both the processing of chemical and natural gas streams exist for this type of construction.

Special Designs

In addition to the general designs of Hypersorption construction outlined in the above three sections, processing conditions permit other variations in overall construction.

When fractionation of two close-boiling components is being carried out, such as the separation of nitrogen and methane in the operation on natural gas, substantial heat economies can be brought about by the heat exchange between the top and bottom of the Hypersorption unit. In this operation heat capacity of the gas streams leaving both the top and bottom are sufficient to control temperature levels in both sections, and heat exchange can be effected between these streams. In this general type of operation, steam is not employed for stripping, and the design is restricted to special processing applications.

Separation Effects Occurring in Hypersorption Unit. Separation of hydrocarbons in the Hypersorption unit involves completely different phenomena from those occurring in the more conventional separating processes. Separation comes about by the forces of attraction between the relatively enormous surface area of activated carbon and the molecules of the gas stream being con-

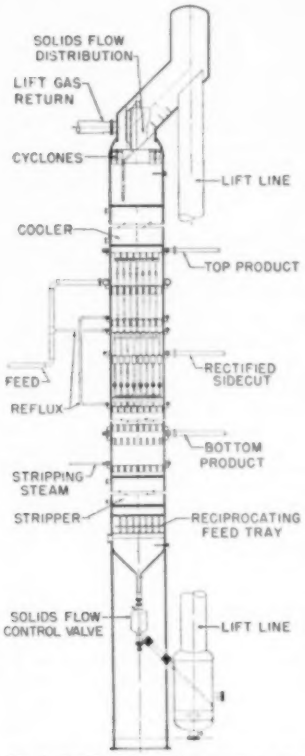

Fig. 4. Rectified side cut Hypersorption unit.

tacted. The adsorbed phase of hydrocarbons itself varies in composition throughout the depth of the adsorbed layer. That portion of the adsorbed layer nearer the solid surface is subjected to the highest adsorption force potentials, whereas at the outer boundary of the adsorbed layer the gases are subjected only to mild compression. The separation effects occurring with

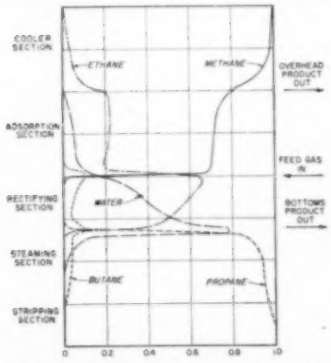

Fig. 6. Composition distribution in Hypersorber separating propane and heavier from natural gas.

contact between activated carbon and the gas stream can be evaluated accurately through the full application of the extensive analyses of plant-performance data and thermodynamic considerations. By the careful evaluation of each of the various phenomena occurring in the chain of adsorption effects, design of a given Hypersorption unit can be completely crystallized. A plot of the change in composition from top to bottom of a Hypersorption unit carrying out the recovery of propane and heavier from a natural gas stream is given in Figure 6. Temperature effects accompanying this separation are given in Figure 7.

The unusual phenomenon of stripping in the Hypersorption process permits the introduction of stripping steam above the bottom heat exchanger rather than below as would be conventionally assumed. This is illustrated in Figures 2, 4 and 5. By this method of introduction, the capacity for stripping in the modern Hypersorption unit has been appreciably increased with greater over-all performance of a given size of Hypersorber. Stripping and liberation of adsorbed compounds in the Hypersorption operation are effected by means quite unlike that in conventional separation processes. The high retentive power of activated carbon is almost completely released in the desorption zone and stripping is effected with ease under a variety of operating conditions.

Activity of Carbon Utilized in Hypersorption Unit. The activated carbon charge of a Hypersorption unit is normally maintained at a relatively high level of activity by reactivation to compensate for whatever accumulations of adsorption oil and polymers of heavy di-olefins may deposit on the carbon. In Figure 8 a plot is given of the activity of the charge of a commercial Hypersorption unit for reactivation operations. Generally speaking, virtually any feed gas can be handled in a Hypersorption unit provided adequate reactivation facilities are designed and put into operation. Adequate activity has been maintained in pilot plant operations employing gas from high-temperature gas-oil cracking containing substantial quantities of C_4 and C_5 di-olefins with heavy acetylenes and probably any normal feed gas will be more easily handled.

Attrition Loss. The Hypersorption process pioneered in the field of solids circulation with the use of the gas lift as an integrated operation. Major refinements have been developed in the gas-lift system employed in the modern Hypersorption units. Attrition loss from present Hypersorption units is one-fifth to one-tenth that encountered in those first constructed. In Figure 9

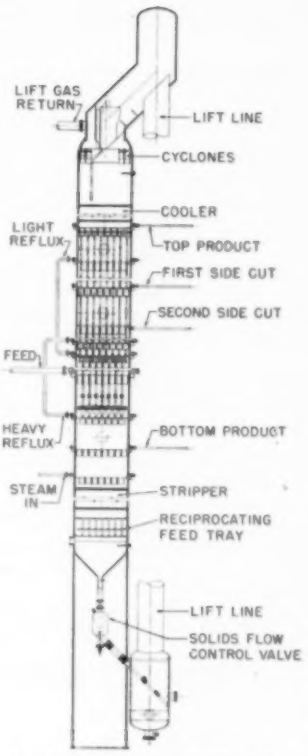

Fig. 5. Four-product Hypersorption unit.

a plot is shown of the attrition loss rate obtained in operation of a modern commercial Hypersorption unit. It will be noted that attrition loss values in commercial operation approach .001 of 1%/cycle. These losses are outstanding in the field of circulation of solids in proc-

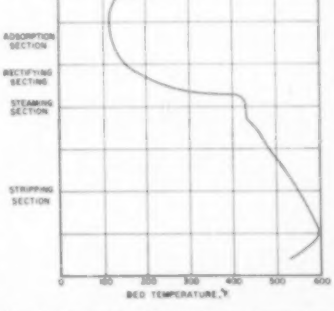

Fig. 7. Temperature distribution in Hypersorber separating propane and heavier from natural gas.

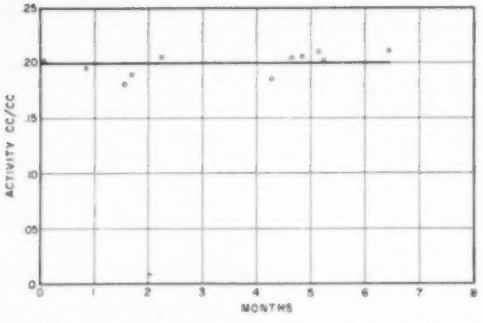

Fig. 8. Carbon activity history of a commercial Hypersorption unit.

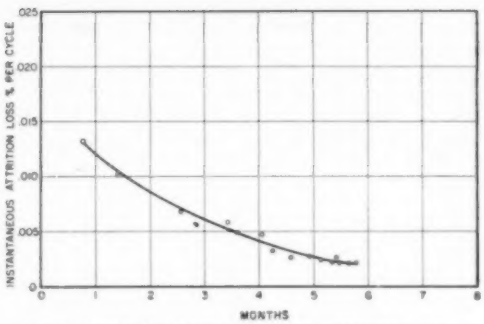

Fig. 9. Attrition loss history of commercial Hypersorption unit.

essing equipment and reflect the high degree of refinement obtained in the design of the gas-lift system.

Application of Hypersorption in Typical Processing Plants

As a general tool for a separation of volatile hydrocarbons and other gaseous compounds, Hypersorption is applicable to a variety of chemical, refining and natural gas operations. In these operations its merits in combining the ability to produce high purity products with high recovery at moderate cost has proved of general interest. Typical applications may be outlined in detail as follows:

To Recovery of Ethylene from a Lean Gas Stream. In Figure 10 is given the process flow sheet of a Hypersorption plant recovering ethylene from a lean gas stream containing 5.8% ethylene and consisting predominantly of hydrogen and methane. This gas stream is the reject from a demethanizing column in a low-temperature fractionating plant. The selectivity and recovery characteristics of the Hypersorption process are amply illustrated by the composition of the product streams from the operation of this plant. These compositions are given in Table 1.

This gas stream normally would be considered as vent gas containing ethylene concentration too low to be economically recoverable by low-temperature operation, but the Hypersorption unit is able to effect 98% recovery of the ethylene content. The product gas stream, termed "make gas" from the operation, is free of contamination of methane within the limits of the analytical tests. This separation of key components in the relatively short adsorption and rectifying bed depth of this commercially operating Hypersorption unit is unique among separation processes.

To Recovery of Ethylene from Refinery Gas Stream with Ethane Cracking. One of the more valuable applications of Hypersorption is in the processing of refinery gas streams to produce ethylene and recover propane and ethane. An example of such a plant employing ethane cracking for maximum ethylene production is presented in Figure 11. Components of the feed gas and product streams are presented in Table 2.

Important steps in the cycle of operation of this plant are as follows:

1. Recovery of ethylene and heavier components from refinery gas stream and ethane cracker effluent in the Hypersorption unit to produce three product streams consisting essentially of C_1's, C_2's and C_3's, respectively.
2. Separation of ethane-ethylene in a small low-temperature column to provide the recycle stream for ethane cracking.
3. Production of the C_3 fraction directly for use as fuel in other chemical processing operations. This fraction can be cracked for a maximum over-all production of ethylene if desired.

A more recent development in Hypersorption processing for this type of plant involves replacing the low-temperature fractionator by a second Hypersorption unit, permitting recovery of an ethylene product of high purity and in addition, recovery of the substantial quantity of hydrogen produced in ethane cracking at more than 99% purity as a fourth product.

To Recovery of Acetylene from Air Oxidation of Natural Gas. The Hypersorption process is valuable in the processing of dilute gas streams for recovery and purification of acetylene. Figure 12 presents a flow sheet of a Hypersorption unit recovering acetylene from gases produced in the air oxidation of natural gas. General steps in operation may be outlined as follows:

1. Air and natural gas are properly preheated and fed to a burner where partial air combustion of the gas occurs. Products of combustion, predominantly nitrogen and hydrogen, carbon monoxide, methane, carbon dioxide, acetylene and ethane, are immediately quenched.
2. Products of combustion are fed to a Hypersorption unit where they are separated into two fractions. Acetylene, ethane and part of the carbon dioxide are adsorbed and produced as a bottoms product, and the balance is produced overhead.
3. The acetylene, ethane, carbon dioxide stream is fed to an absorption-stripping system, and 98% pure acetylene is produced overhead from the stripper and ethane-carbon dioxide concentrate released overhead from the absorber.

TABLE 1

APPLICATION OF HYPERSORPTION TO THE RECOVERY OF ETHYLENE FROM A LEAN GAS STREAM

Comp.	Feed Gas, Vol. %	Bottoms Product, Vol. %	Overhead Product, Vol. %	Purge Gas, Vol. %
Hydrogen	39.8	-	31.6	61.8
Nitrogen	4.7	-	1.4	2.5
Carbon Monoxide	0.9	-	0.8	1.3
Oxygen	0.1	0.1	0.1	0.2
Methane	51.3	-	66.1	33.7
Carbon Dioxide	0.2	2.9	-	0.1
Acetylene	0.2	3.6	-	-
Ethylene	5.8	92.7	-	0.4
Ethane	Trace	0.7	-	-
Total	100.0	100.0	100.0	100.0

TABLE 2

APPLICATION OF HYPERSORPTION TO THE RECOVERY OF ETHYLENE FROM A REFINERY GAS STREAM

Composition	Ref. Gas	Hyper. Feed	Ovhd. Prod.	Botts. Prod.	Hyper. Side Cut	Ethyl. Fract. Ovhd.
Hydrogen	8.23	11.91	25.40			
Methane	51.55	35.46	73.92		0.54	1.35
Ethylene	3.92	13.24	0.35	1.79	39.32	97.11
Ethane	22.58	25.18	0.33	3.44	59.84	1.54
Propylene	6.18	4.42		29.35	0.16	
Propane	11.94	8.32		54.30	0.14	
C_4's+	1.60	1.47		11.12		

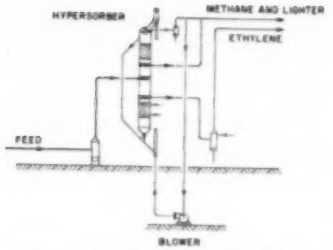

Fig. 10. Hypersorption plant recovering ethylene from lean gas stream.

A general breakdown of stream compositions is given in Table 3.

To Separation of Nitrogen from Natural Gas. The Hypersorption process provides a valuable means for separation of nitrogen from low B.t.u.-content natural gas. Simultaneous with the upgrading of the low B.t.u.-content natural gas, recovery of ethane, propane and butane is effected. In Figure 13 a flow sheet is presented for carrying out this operation, and in Table 4 compositions of the streams in this plant are presented.

The sequence of operations may be outlined as follows:

1. The natural gas first enters a three-product Hypersorption unit where the methane is taken overhead, ethane as the first side cut, propane as the second side cut, and butane and heavier as the bottoms product.
2. Methane and nitrogen are further processed in a second Hypersorber which produces nitrogen overhead and methane as the bottoms product. This Hypersorber incorporates the economics of elimination of cooler- and stripper-tube bundles described in the section dealing with special design.
3. Ethane is reblended with the methane for pipe-line delivery of specification B.t.u.-content gas. Propane and heavier components are delivered as a separate stream for use in *LPG* and gasoline blending.

Figure 14 shows the world's largest Hypersorption unit recently completed at the Dow Chemical Co., Midland, Mich.

Acknowledgment

The author wishes to express his appreciation to the Union Oil Company

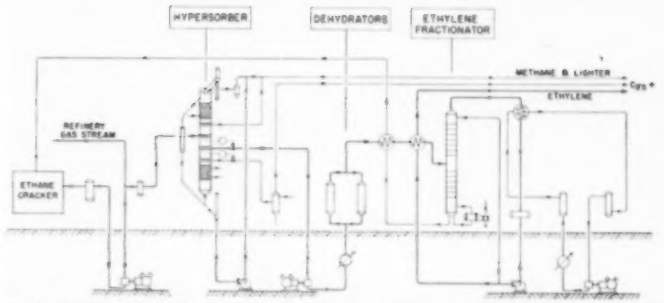

Fig. 11. Hypersorption plant for recovery of ethylene from refinery gas streams with ethane cracking.

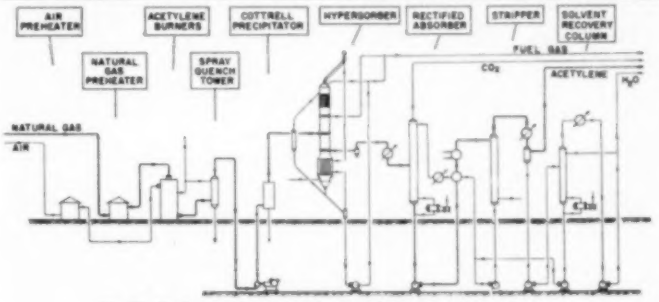

Fig. 12. Production of acetylene by partial oxidation of natural gas.

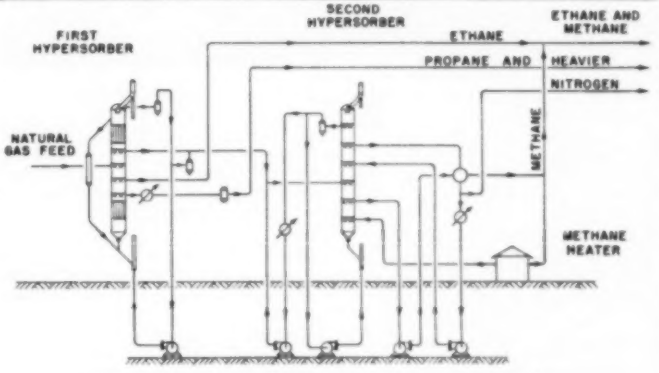

Fig. 13. Hypersorption plant for separation of nitrogen from natural gas.

TABLE 3

APPLICATION OF HYPERSORPTION TO THE RECOVERY OF ACETYLENE FROM AIR OXIDATION OF NATURAL GAS

Composition	Feed	Comb. Prod. Gases	Hyper. Ovhd. Prod.	Hyper. Botts. Prod.	Rectified Absorber Overhead	Stripper Overhead
Hydrogen	-	24.3	25.9	-	-	-
Nitrogen	-	54.5	58.0	-	-	-
Carbon Monoxide	-	9.4	10.0	-	-	-
Carbon Dioxide	4.3	3.5	2.1	24.6	52.9	2.0
Methane	84.3	3.6	3.8	0.3	0.7	-
Acetylene	-	3.5	-	56.0	3.7	98.0
Ethane	6.8	1.0	0.1	15.8	35.3	-
Propylene and Heavier	4.6	-	-	-	-	-
Ethylene	-	0.2	-	3.3	7.4	-

TABLE 4

APPLICATION OF HYPERSORPTION TO THE SEPARATION OF NITROGEN FROM NATURAL GAS

First Hypersorber

Comp	Feed, Mol %	Overhead, Mol %	Side Cut, Mol %	Bottoms, Mol %
N_2	29.6	33.5	-	-
CH_4	58.6	66.3	0.4	-
C_2H_6	6.1	0.2	99.1	0.5
C_3H_8	4.6	-	0.5	80.2
C_4H_{10}'s	1.1	-	-	19.3

Second Hypersorber

Comp.	Feed, Mol %	Overhead, Mol %	Bottoms, Mol %
N_2	33.5	99.0	0.8
CH_4	66.3	1.0	98.9
C_2H_6	0.2		0.3

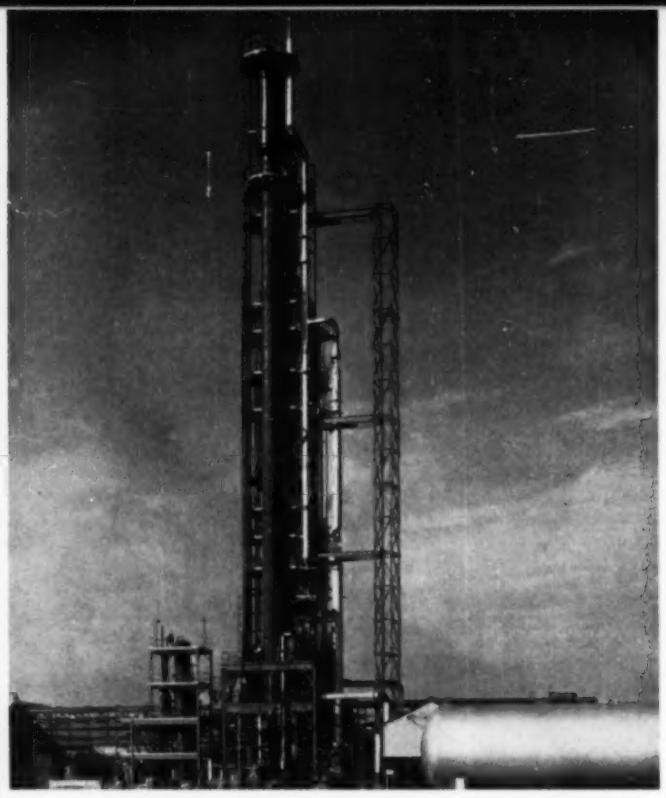

Fig. 14. Photograph of Hypersorption unit recently completed at the Dow Chemical Co., Midland, Mich.

for permission to publish this review of modern advancements in Hypersorption design.

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Discussion

H. E. Rasmussen (Socony Vacuum Oil Co., Paulsboro, N. J.): Is the Hypersorption process applicable for separating olefins from paraffins with the same number of carbon atoms; for example, ethylene from ethane?

Clyde Berg: That's a good question. It is feasible to separate ethane and ethylene in Hypersorption units. The separation is more difficult than the separation of classes of hydrocarbons differing in the number of carbon atoms just as you might expect. The separation of ethane and ethylene can be effected, however, and where it might be desirable to incorporate such design it could be done.

B. F. Koepke (Aluminum Co. of America, 2300 Power and Light Bldg., Kansas City, Mo.): I couldn't help but reflect, in view of the difficulties many of the natural gasoline manufacturers are having today in the dehydration of the residue gas, what the economics might be with respect to the application of the Hypersorption process for the removal of the absorption oil that is carried over, and to bring about or produce a little Du Pont residue gas.

Clyde Berg: Designs have been completed for applications similar to those of the nature of which you have mentioned. It is best to combine the recovery of *LPG* with the processing of your natural gas stream, to augment the economic justification. It is doubtful you would set up the equipment to remove water alone since a substantial return from products is generally required to pay off the processing equipment.

B. F. Koepke: I was thinking of removing the moisture and also the oil.

Clyde Berg: When we process a stream in the Hypersorber we do remove the water, in fact completely. The dew point or the overhead of a Hypersorber will probably be below −120° F.

G. A. Agoston (Kerr-McGee Oil Co., Oklahoma City, Okla.): Would you explain the operation of the reciprocating feed tray shown at the bottom?

Clyde Berg: The reciprocating feed tray is a positive displacement device for setting uniform solids flow in the column. This device is actually a combination of three trays; two stationary and one moving. The top tray directs solids flow into a number of down spouts in the moving tray. These serve as positive displacement chambers. The bottom tray, which is stationary, has a number of openings and permits discharge of the down spouts in the displacement tray at the proper position. As the displacement tray moves from one side of the tower to the other it is alternately filled and discharged and since the pockets in the tray are uniformly distributed across the area of the tower, there is an equal volume of solids removed from the base of the unit across every square foot of tower area. By speeding up the motion of the tray, it is possible to increase the total flow or by slowing it down it is possible to decrease it.

H. N. Woebcke (Hydrocarbon Research, Inc., New York): In production of acetylene by the partial oxidation of methane, higher acetylenes are also produced. Have you any operating data on the performance of activated charcoal in the Hypersorber in treating raw gas containing higher acetylenes?

Clyde Berg: We have operated in the presence of the higher acetylene and vinyl acetylene. The higher acetylenes are unstable and a portion will polymerize but this merely increases the requirements for this reactivation by the water gas reaction. Actually, the amount of those heavy acetylenes varies from process to process depending on the technique of the air combustion operation. Some operations are almost free of heavy acetylenes. There are a number of chemical companies that have studied and developed this combustion technique.

H. I. Wolff (Shell Chemical Corp., W. Hempstead, N. Y.): In order to orient an evaluation of your design would you care to say something about how far you have gone in your pilot plant or commercial operations in relation to the various designs?

Clyde Berg: Were you thinking of the acetylene operation alone or of all designs?

H. I. Wolff: I'm thinking of all the designs.

Clyde Berg: The ethylene refinery operations are commercial, I would say.

There are a number of plants dealing with ethylene. The acetylene operation is in commercial design study stage. The pilot plant operations associated with commercial construction have been completed and all the processing operations are well crystallized. The natural gas operation for nitrogen removal has been studied considerably in experimental stages and the general economics of nitrogen removal are well established.

R. H. McKee (Columbia University, New York): It is apparent that where normally we want a dense, adsorbent carbon, here is an opportunity to use a light, adsorbent carbon. Is this not so?

Clyde Berg: The question of the quality and nature of the activated carbon to be used is certainly an important one. There are certain basic factors which must be considered in the selection of activated carbon for this purpose. First, it must be exceptionally hard and abrasion-resistant, so that it will not wear out too rapidly. But beyond that, it is possible to vary density between light and heavy. A light adsorbent carbon has large pores and would be particularly useful where you have constituents which are rather readily adsorbed and you wish as much volume as possible to carry these constituents down through the unit; on the other hand, where you have difficultly adsorbable constituents the finer pores present in a more dense carbon, are most useful.

E. J. Fradkin (Chemical Construction Corp., New York, N. Y.): Did I understand that the diacetylenes must be removed prior to the treatment, and do you have any idea of what the product gas composition would be with a 10% acetylene feed?

Clyde Berg: To your first question: I did not say the diacetylenes would have to be removed. If they are present in moderate quantities they can be handled within the unit operation itself. Now if you have a high content of diacetylene which is difficult to handle in any sort of unit it would probably be better to get rid of it by the easiest means available. It would be necessary to study the operation and decide upon the best way of handling it.

For the 10% acetylene feed which would be characteristic of the gas produced in partial oxidation of natural gas with pure oxygen, we would obtain hydrocarbon products similar to those shown in the flow sheet; however, we would not have nitrogen contaminating the overhead. Beyond that, the general processing requirement of purifying the final acetylene in the solvent extraction stages would be much the same.

(Presented at Kansas City (Mo.) Meeting.)

ABSTRACTS

Abstracts of current articles published in Chemical Engineering Progress Symposium Series, No. 1, Vol. 47, Ultrasonics—Two Symposia. Volumes are on sale from Chemical Engineering Progress, 120 E. 41st Street, New York 17, New York.*

BASIC PRINCIPLES OF THE APPLICATION OF SONIC AND ULTRASONIC ENERGY

Egon A. Hiedemann

Michigan State College

THE use of sonic energy for measurement and for testing in the chemical industry is discussed. Advantages of the utilization of elastic waves in testing and control, e.g., measurement of mechanical properties; study of solidification; control of composition of gas mixtures; and changes in state, are shown. Other topics covered are: dispersion; coagulation; mass transport; degassing of melts; improvement of grain structure, of acoustic conditions in different states of aggregation; generators; problem of applying ultrasonic energy.

Chem. Eng. Progress Symposium Series—"Ultrasonics," **47**, No. 1, 56 (1951).

ON THE MECHANISM OF BIOLOGICAL EFFECTS PRODUCED BY ULTRASOUND

T. F. Hueter

Massachusetts Institute of Technology

PHYSICAL parameters likely to cause biological changes and biological environmental conditions affecting threshold levels are systematically reviewed. A classification of experimental conditions is given, supported by evidence gained through controlled experiments, to illustrate how cells and organisms respond to ultrasonic irradiation. Effects upon blood, bacteria, nerve tissue, and data on pain threshold levels are included. Work in connection with tumors, tuberculosis germs, vaccines, etc., is noted, as well as the application of ultrasound to industrial uses.

Chem. Eng. Progress Symposium Series—"Ultrasonics," **47**, No. 1, 62 (1951).

KILOWATTS OF ULTRASONIC POWER FOR INDUSTRY

J. W. Butterworth

Brush Development Co.

DEVELOPMENTS in design and construction of high power ultrasonic generators are discussed. Data are given on the building of a 2-kw. pilot plant transducer, including reference to such problems as prevention of cavitation and gassing in the transmission medium, and to improved techniques for its utilization; and also on acoustic impedance and piezoelectric materials, and use of barium titanate. Illustrations include a comparative chart of piezoelectric crystals, and typical forms of fabricated barium titanate.

Chem. Eng. Progress Symposium Series—"Ultrasonics," **47**, No. 1, 76 (1951).

PHYSICAL AND ECONOMIC LIMITATIONS IN THE APPLICATION OF SONIC AND ULTRASONIC ENERGY TO INDUSTRIAL PROCESSING

R. W. Somsel

General Electric Company

THE following points are developed: Cavitation or mechanical strength of the medium limits sound intensity. Objectionable heating may result from high intensities, representing energy loss. The generator is limited by the mechanical strength of its parts and its inability to operate at high temperatures. Inherent saturation limits of some materials curtail increased output. When the characteristics of the sound source cannot be made to match the load an attendant loss results. Adequate power is not always available.

Chem. Eng. Progress Symposium Series—"Ultrasonics," **47**, No. 1, 84 (1951).

Publication of the Monograph and Symposium Series has been undertaken to meet the increasing demand for more chemical engineering information in published form.

The first volume of Chemical Engineering Progress Monograph Series, No. 1, Vol. 47, Reaction Kinetics in Chemical Engineering, by Professor Olaf Hougen of the University of Wisconsin, is now also available. (Abstract, page 528 of the October issue.)

Prices: Members, Reaction Kinetics in Chemical Engineering $2.25; Ultrasonics—two symposia $2.00; both volumes $4.00. Nonmembers, Reaction Kinetics in Chemical Engineering $3.00; Ultrasonics—two symposia $2.75; both volumes $5.50. (Paper covered.)

Volumes will be sent as issued to subscribers entering an order on a yearly basis.

**(See advertisement, page 55 of October issue for details; also editorial, page 444 of the September issue.)*

CAST ALLOY REFERENCE SHEET

N. S. MOTT, Chief Chemist Metallurgist
The Cooper Alloy Foundry Co., Hillside, N. J.

ALLOY: CORROSION-RESISTANT LOW CARBON 18% CHROMIUM 8% NICKEL 3% MOLYBDENUM ALLOY.

APPLICATIONS AND REMARKS: The addition of molybdenum to the 18-8S analysis at a cost increase of about 6 cents a pound over the base material results in a great improvement in resistance to corrosion of all forms, i.e., general, pitting, and intergranular. Excellent resistance is accomplished in such corrosive media as hot organic acids, fatty acids at high temperatures, chlorides, acid salts, hot sulfite liquors, etc., making the alloy suitable for adaptation in manufacturing processes handling such. Castings are made of this alloy for valves, pumps, fittings, and for many special designs.

DESIGNATIONS: ACI CF-8M; AISI 316; SAE 60316; ASTM A296-49T, Grade CF-8M.

CHEMICAL COMPOSITION RANGE: C < .08%; Cr 18-21%; Ni 9-12%; Si < 1.5%; Mo 2-3%.

MACHINABILITY: 18-8S Mo is tough, ductile and is characterized by its work hardening and high frictional properties. Best results for turning are obtained by using a slow heavy cut. To avoid work hardening the surface care should be taken not to allow the tool to ride or glaze the work. Sharp tools with a large rake are desirable, and chip curler tools are recommended. It is slightly easier to machine than 18-8S.

HEAT TREATMENT: If carbides are not put into solution intergranular corrosion may result. To avoid this all castings are water-quenched from 1950-2050° F. before being put into corrosive service. The time at temperature is from 1 to 3 hrs. depending upon metal thickness.

WELDABILITY: 18-8S Mo may be readily welded by the usual methods using a type 316 filler rod. In the welded condition, however, it is subject to intergranular corrosion or weld decay in areas adjacent to the weld deposit. To avoid this water - quenching of the work from 1950-2050° F. is necessary.

MECHANICAL AND PHYSICAL PROPERTIES.

Tensile Strength, 1000 lb./sq.in.	90	Melting Point	2500-2550° F.
Yield Point, 1000 lb./sq.in.	55	Specific Heat (B.t.u./(lb.)(° F.) 32-212° F.	0.12
Elongation, %	50	Thermal Expansion (× 10⁻⁶in./(in.)(° F.) 32-212° F.	8.9
Reduction in Area, %	55	Thermal Conductivity (B.t.u./(hr.)(sq.ft.)(° F./in.)) 32-212° F.	108
Brinell Hardness	155	Electrical Resistance (Ohms/cir. mil. ft.) @ 32° F.	420
Charpy Impact (Std. Keyhole ft.-lbs.)	58		
Mod. of Elasticity (× 10⁶ lb./sq.in.)	28		
Specific Gravity	8.00		

CORROSION RESISTANCE

ACIDS

Acetic 5%, 70 F	E
Acetic 5%, boiling	E
Acetic 80%, 70 F	E
Acetic 80%, boiling	E
Acetic Glacial, 70 F	E
Acetic Glacial, boiling	E
Benzoic 5%, 70 F	E
Boric 5%, 176 F	E
Chromic 10%, 70 F	E
Chromic 10%, boiling	G
Chromic 50%, boiling	F
Citric 5%, 70 F	E
Citric 25%, boiling	E
Citric 50%, boiling	E
Formic 5%, 70 F	E
Hydrochloric 1%, 70 F	G
Hydrochloric 1%, boiling	N
Hydrochloric, 5%, 70 F	P
Hydrochloric 5%, boiling	N
Hydrochloric 25%, 70 F	N
Hydrochloric 25%, 176 F	N
Hydrofluoric 48%, 70 F	P
Hydrofluoric 48%, 176 F	N
Lactic 5%, 70 F	E
Malic, all temps.	E
Nitric all concs., 70 F	E
Nitric 65%, boiling	E
Oleic all concs., all temps.	E
Oxalic 5%, boiling	E
Phosphoric 10%, 70 F	E
Phosphoric 85%, 70 F	E
Phosphoric 85%, boiling	N
Stearic concentrated to 200 F	E
Sulfuric 2%, 70 F	E
Sulfuric 2%, 176 F	E
Sulfuric 2%, boiling	F
Sulfuric 5%, 70 F	E
Sulfuric 5%, 176 F	G
Sulfuric 5%, boiling	F
Sulfuric 10%, 70 F	E
Sulfuric 10%, 176 F	G
Sulfuric 10%, boiling	N
Sulfuric 78% (60° Be), 176 F	N
Sulfuric 93% (66° Be), 70 F	E
Sulfuric 93%, 300 F	N
Oleum, 70 F	E
Mixed Acids 57% H_2SO_4, 28% HNO_3, 176 F	E

ALKALIES

Ammonium Hydroxide, all concs.	E
Calcium Hydroxide Sat., 70 F	E
Calcium Hydroxide Sat., boiling	G
Sodium or Potassium, Hydroxide, all concs., 70 F	E
Sodium or Potassium Hydroxide < 20%, boiling	E
Sodium or Potassium Hydroxide 30% boiling	G
Sodium or Potassium Hydroxide, Molten, 600 F	N

NEUTRAL AND ALKALINE SALTS

Barium Sulfide, 70 F	G
Calcium Chloride 5%, 70 F	E†
Calcium Sulfate Sat., 70 F	E
Magnesium Chloride 5%, 70 F	E†
Magnesium Sulfate 5%, 70 F	E
Sodium Carbonate, all concs., 70 F	E
Sodium Chloride 5%, 70 F	E†
Sodium Sulfate 5%, 70 F	E
Sodium Sulfide 5%, 70 F	E
Sodium Sulfite 5%, 70 F	E

ACID SALTS

Alum 10%, boiling	E
Aluminum Sulfate 10%, 70 F	E
Ammonium Chloride 5%, 70 F	E
Ammonium Sulfate 10%, 70 F	E
Ammonium Sulfate 10%, boiling	G†
Ammonium Nitrate, all concs., 70 F	E
Stannous Chloride 5%, 70 F	G†
Zinc Chloride 5%, boiling	F†

OXIDIZING ALKALINE SALTS

Calcium Hypochlorite 2%, 70 F	G†
Sodium Hypochlorite 5%, 70 F	G†
Sodium Peroxide	E

OXIDIZING ACID SALTS

Ammonium Persulfate 5%, 70 F	E
Cupric Chloride 1%, 70 F	F†
Cupric Sulfate 10%, 70 F	E
Ferric Chloride 10%, 70 F	F†
Ferric Sulfate, boiling	E
Mercuric Chloride 2%, 70 F	F†
Stannic Chloride 5%, 70 F	F†

WET AND DRY GASES

Chlorine Gas Dry, 70 F	G
Chlorine Gas Wet, 70 F	P†
Sulfur Dioxide Dry, 575 F	E
Sulfur Dioxide Wet, 70 F	E
Sulfur Dioxide Solution, 70 F	G
Sulfur Dioxide Spray, 70 F	F†
Hydrogen Sulfide Dry	E
Hyrdogen Sulfide Wet	E

ORGANIC MATERIALS

Acetone, 70 F	E
Acid Sludge (50% H_2SO_4), 200 F	N
Alcohol—Methyl and Ethyl	E
Aniline Hydrochloride, 70 F	P
Benzol, 176 F	E
Carbon Tetrachloride	E
Chloroform	E
Ethyl Acetate, 70 F	E
Formaldehyde, 70 F	E
Phenol 5%, boiling	E
Refinery Crudes	E
Trichlorethylene, boiling	E

PAPER MILL APPLICATIONS

Kraft Liquor	E
Black Liquor	E
Green Liquor	E
White Liquor	E
Sulfite Liquor, 176 F	E
Chloride Bleach	G†
Paper Makers Alum	E

PHOTOGRAPHIC INDUSTRY

Humid Atmospheres	E
Cellulose Acetate	E
Acetic Anhydride	E
Acetic Acid + 1% H_2SO_4	F
Developers	E
Solutions Containing SO_2	G
Silver Nitrate, 70 F	E

FERTILIZER MANUFACTURING

$H_3PO_4 + H_2SO_4 + HF$	F

PICKLING OPERATIONS

H_2SO_4 + Dichromate, 176 F	E
H_2SO_4 + Hcl, 176 F	N

CORROSIVE WATERS

Acid Mine Water	E
Abrasive Acid Mine Water	F
Sea Water	G
Brackish Water	E

FOOD & ASSOCIATED PRODUCTS

Brines	E
Edible Oils	E
Fats	E
Fatty Acid Distillation	E
Fruit Juices	E
Ketchup	E
Milk Pasteurizing	E
Vinegar and Salt, 70 F	E

RATINGS:

E—Excellent resistance. 0.001 max. in. per year of penetration. Corrosion so slight as to be harmless.
G—Good resistance. 0.001-0.002 in. per year of penetration. Satisfactory service expected; at most a slight etch.
F—Fair resistance. 0.002-0.020 in. of penetration per year. Satisfactory service under specific conditions. Light to moderate attack.
P—Poor resistance. 0.020-0.120 in. of penetration per year. Satisfactory for temporary service only.
N—No resistance. 0.120 min. in. of penetration per year. Rate of attack too great for any use.
†—Subject to pitting type corrosion.

No. 5
(FIFTH OF A SERIES OF TEN)

ATLANTIC CITY MEETING

Chalfonte - Haddon Hall, Headquarters for Forty-fourth Annual Meeting

Article by L. C. Knox

THE state of New Jersey, so the Atlas tells us, is a leading producer of refined petroleum, chemicals, glass, pottery, and textiles and among its great centers of industry are Newark, Trenton, and Camden. A more imaginative source would never have missed what many an Easterner thinks of as Jersey's most typical product, salt water taffy, nor the seat of its manufacture, Atlantic City. Salt water taffy, for the benefit of the uninitiated, is a tasty confection which, as Mr. Ripley was so fond of telling us, is not made with salt water. And Atlantic City (is there anyone uninitiated?) is the Atlantic coast's resort of resorts, and, incidentally, the site of next month's Forty-fourth Annual Meeting of A.I.Ch.E., Dec. 2-5.

Putting on course of Atlantic City Country Club.

Atlantic City—One Big Enterprise

As a matter of fact, salt water taffy, or rolling chairs, or Miss America for that matter, is just one product of a vast business whose over-all purpose is selling a vacation to the army of sunbathers - swimmers - boardwalkers who perennially invade those few square miles of water-surrounded sand. And the business involves everybody. From the fishhouses on the Inlet to the tip of Longport, directly or indirectly, almost every citizen works in it, housing, selling, serving, driving, entertaining—all to such an extent that the city and the business it produces are almost completely merged into one city enterprise.

It's Not All Taffy

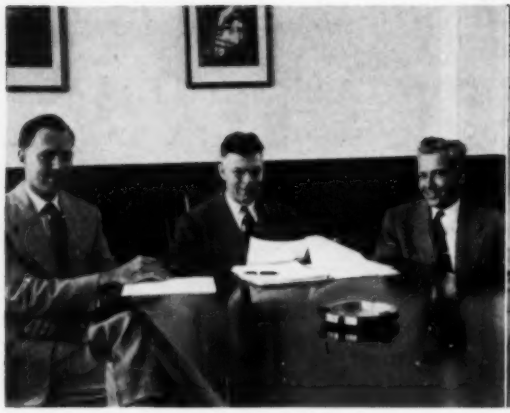
Atlantic City takes this business of being the East's most thoroughgoing seashore resort seriously, as well it might. First of all, it's big. Its summer population runs to several hundred thousand. Second, for a resort, it's metropolitan. Lining the city's beachfront promenade, the "boardwalk," are block-long hotels, restaurants, even legitimate theaters. The city boasts more night life than many a bigger town nearby. All in all it has a decided big-city look which blends startlingly, but pleasantly enough, with its holiday air and seaside situation. And finally, just in case anyone might want to use it, the city has a bathing beach at least the equal of anything on the Atlantic Coast.

A.I.Ch.E. conventioneers, to be sure, will hardly be interested in surf bathing in December, but if things follow their normal course, the weather will be mild enough for a taste of the shore vacationist's favorite outdoor sport: strolling along the boardwalk. The boardwalk looms large as the social center in Atlantic City. It will be crowded not only in the summertime when the standard attire is sun dress, slacks and sports clothes, but at other holiday times through the year. Thousands of New Yorkers and Philadelphians would never miss the opportunity to display newly acquired finery on the wooden boulevard at Easter or Christmas, and pictures in the metropolitan press of this recurring ritual of seeing and being seen are as regular and heavily sanctioned as the weather report.

Left to right: B. E. Milner, chairman, Meals Comm., and W. E. Osborn, secretary, General Comm.

Great Expectations

Things to be seen line the boardwalk on both sides and they run the whole gamut: from hotels, restaurants, movies, shops to "knock-down-the-baby" and "guess-your-weight," from the very toney to the considerably less than toney, but mostly comfortably in-between. Several of the "amusement piers" are typical of the whole boardwalk atmosphere. These platforms that project out over the beach at right angles to the boardwalk were once almost entirely over water, although now only the ends of them get wet, because of the general building-up of the beach. One of these piers, for example, combines an amusement park, a variety show, a circus,



Left to right: T. A. Burtis, chairman, Public Relations Comm.; W. H. Barcus, vice-chairman, General Comm., and J. L. Olsen, chairman, Registration Comm.

Left to right: W. E. Chalfant, chairman, Entertainment Comm.; H. L. Bolton, chairman, Hotel and Meeting Rooms; W. T. Dixon, chairman, General Comm., and Mrs. W. T. Dixon, Ladies Program. Standing: S. D. Ross, chairman, Printing and Signs Comm.

movies, an animal act, and a hodgepodge of commercial exhibits into one entertainment meal that takes the better part of a day to consume. Another one has a legitimate theater and a concert hall. A third specializes in amusing the children. And so on, from one end of the boardwalk to the other. Of course, if you're not up to all the foot-flattening exercise involved in taking in the sights, you can always ride in one of Atlantic City's basketwork rickshaws, the trademark of the boardwalk, a rolling chair.

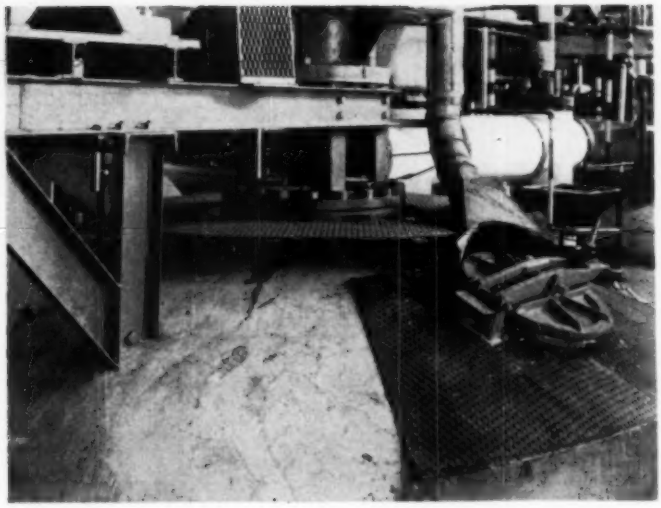
Walking the Boards

Of all the capital assets of the enterprise, the city values the boardwalk the highest. (Mere maintenance of it is the job of a special city department and costs run into six figures annually.) Obviously this evaluation is correctly made, because the boardwalk and the streets right near it are not only the heart of the city, but also are practically all of it that many vacationers ever see. Back from the walk, back behind the big hotels, the town looks much more the medium-sized provincial city, much more what one would expect of a resort. This part of the city looks more like the town which would have grown in a scant hundred years from a small village in the shadow of the old Absecon Light. Actually it did just that. It was a new railroad, built to serve South Jersey's old handcraft glassworks, that gave the village its start as a resort. Now with the glassworks all but gone and the old light a half-mile inland, Atlantic City, still aided and abetted by the railroad and more so by the motorcar, has outgrown all of them. Now it has filled the island, back to the western edge, down to the south where its suburbs Ventnor, Margate, and Longport boast some of the finest and fanciest villas this side of Los Angeles, and east as far as the ocean and the boardwalk will permit.

"By the sea, by the sea, by the beautiful sea."

So there you have it, our premeeting Baedeker for Atlantic City: the town, what to see, even some history. There's one more thing. One is never supposed to return empty-handed from a junket like the December meeting, but what to take home occasionally becomes a bothersome question. You know how it is. At 3 P.M. on Wednesday afternoon you start after the train and just then you remember. Perfume? Bric-a-brac? Something for the children?

When one leaves Atlantic City, such difficult decisions need never be faced. Atlantic City has a ready-made, all-purpose, all-weather solution. There is no recorded instance of its ever having failed one individual out of the millions and millions who have come and gone. It is available at any one of at least 186 places on and off the boardwalk, in all colors, shapes, and sizes. You'll take it home too; you won't be able to avoid it. It's salt water taffy.



The picture above shows the skid-proof metal plates of the Industrial Mineral Wool Institute, New York, which protect insulation around the center and hatch of a reaction kettle at a Pennsylvania chemical plant. Employees formerly braced their feet against the insulation itself to remove the hatch cover. Additional expense of the metal plates is small compared to savings obtained through reduced maintenance. The kettle at 550° F., is covered with 3-in. thick mineral wool blankets finished with insulating cement. This improvement is in line with the principle of isolating insulating surfaces from accidental damage by plant personnel.

CARBIDE TO RUN NEW A.E.C. PLANT

The Atomic Energy Commission has signed an agreement with Union Carbide and Carbon Corp., operator of the three Oak Ridge atomic energy facilities, for the operation of the new Uranium-235 production plant in Paducah, Ky., it was announced recently by Marion W. Boyer, A.E.C.'s general manager.

Under the terms of the agreement, Union Carbide will not only staff and operate the Paducah gaseous diffusion plant, but also perform much of the process design, engineering, and development work in connection with the new production facilities, and arrange procurement of a large part of the special equipment required.

Carbide will operate the closely related Paducah and Oak Ridge plants under a single organization centered in Oak Ridge. The 500-million-dollar facility is now being built for the A.E.C. by F. H. McGraw and Co., Inc. of Hartford, Conn., under contract of the Commission.

Carbide's organization for operating the new Paducah plant will be headed by G. T. Felbeck, vice-president of Carbide and Carbon Chemicals Co., and Clark E. Center, general manager of Carbide's atomic energy operations in Oak Ridge. J. P. Murray has been appointed plant superintendent at Paducah. Carbide's operating personnel there will number about 1,600.

ACHEMA X IN FRANKFORT

Frankfurt-on-Main will be the location of Achema X, the European exhibit of chemical equipment, on May 18-25, 1952. The exhibit is held by the Dechema Deutsche Gesellschaft f. chem. Apparatewesen E.V.

The Societe de Chimie Industrielle will hold its 25th International Congress for Industrial Chemistry at the same time, along with several other meetings of German groups.

It is expected that this exhibition will utilize seven exhibition halls instead of the usual five.

PERKIN AWARD TO BURNS, BELL TELEPHONE

Robert M. Burns, chemical director of the Bell Telephone Laboratories, Murray Hill, N. J., has been chosen to receive the Perkin Medal, according to an announcement made by Gustavus J. Esselen, chairman of the Jury of Award, and vice-president of the United States Testing Co. The Jury of Award of the Perkin Medal consists of representatives of American Chemical Society, American Institute of Chemical Engineers, Electrochemical Society and the American Section of the Societe de Chimie Industrielle, in addition to officers of the American Section of the Society of Chemical Industry, under whose auspices the medal is awarded. The formal award of the medal to Dr. Burns is scheduled for Jan. 4, 1952, following a dinner in the medalist's honor at the Waldorf-Astoria, New York.

Dr. Burns' accomplishments include applications of chemistry to problems of the communications industry, notably in control and prevention of corrosion; development of primary batteries, cadmium lead storage cells and electrolytic capacitors employing aluminum and tungsten; development of ceramic and high polymer insulating and structural materials and the artificial growth and utilization of large piezoelectric crystals for the control of electronic circuits.

NEW METAL CARBIDE

An entirely new tungsten- and cobalt-free family of metallic carbides having physical properties better in many respects than conventional tungsten carbides is now in the limited pilot plant stage, and expansion is underway for full production by the Carboloy department of General Electric Co.

Known as Series 600, the new carbide, produced from powdered metals, contains approximately 70% by weight of chromium and is thus primarily a "chrome-carbide." Field tests on several applications have been completed. It eliminates costly and strategic tungsten and cobalt.

Outstanding properties of Series 600 according to G.E., include high resistance to abrasion, erosion and corrosion; lighter weight; a coefficient of thermal expansion approximately the same as that of steels; and extreme resistance to oxidation even at high temperatures. It is completely nonmagnetic.

Although the new material may find some applications where tungsten carbides are used at present—it is not expected to supplant the latter, since its properties supplement rather than "compete" with conventional tungsten carbides.

In valves used in the petroleum industry, chrome carbide balls used in combination with Grade 55A tungsten carbide valve seats, Series 600's performance is traceable to a combination of lighter weight (less pounding) than tungsten carbide balls; and its greater ability to resist abrasion, corrosion and particularly erosion.

This combination also accounts for its application in centrifuge blades.

MANPOWER CONVOCATION A REAL SUCCESS

A joint meeting arranged by the Engineering Manpower Commission of Engineers' Joint Council and the Engineers' Society of Western Pennsylvania at Stephen Foster Memorial Hall, University of Pittsburgh, late in September, was an unqualified success in getting over to the industrialists who attended, the message that engineering manpower is in critical short supply and local programs should be started to inform the public on the danger.

The convocation attracted some 500 delegates from 28 states. Many delegates who were there were fully cognizant of the shortage of engineers but interested in learning how to run such convocations in their own sections of the country. The need for this was touched upon by Carey H. Brown, manager of engineering and manufacturing services of Eastman Kodak Co., and chairman of the Engineering Manpower Commission of E.J.C., who called upon the engineering profession to broadcast facts on the shortage of engineers and disseminate this information to its own local communities.

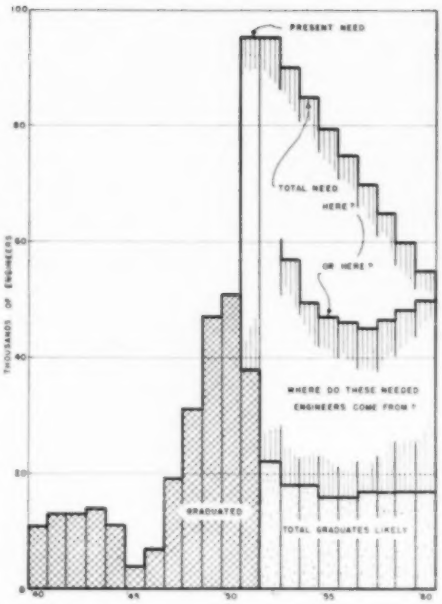
Speakers at the morning session were: A. C. Monteith, vice-president of Westinghouse Electric Corp., S. C. Hollister, Dean of Cornell University, M. H. Trytten of the National Research Council, Washington, D. C., and C. H. Brown.

An open forum was held in the afternoon, presided over by G. A. Shoemaker, vice-president of the Pittsburgh Consolidation Coal Co. Questions were addressed to other experts in the field—Adm. Ben Moreell, president of Jones and Laughlin Steel Corp. and a former member of the Scientific Manpower Advisory Committee; J. C. Warner, of Carnegie Tech; Douglas Brown, dean of faculty at Princeton University; P. N. Powers, assistant to the president of Monsanto Chemical Co. and former secretary of the Scientific Manpower Advisory Committee.

Stressed during the conference was the concept of highest individual contribution to the defense effort as a substitute for the democratic and traditional concept of equality which is sacrificed.

HOOVER RECEIVES A. S. A. AWARD

The Howard Coonley Medal of the American Standards Association was awarded Oct. 24 to Herbert Hoover at the Waldorf-Astoria at a luncheon ending a three-day session of A.S.A. The former President was cited for his work on standardization, simplification and specification which began back in 1921 when he was Secretary of Commerce, including the creation of the Bureau of Standards and which has continued down to his recent report on the reorganization of the Executive Department of the Government.



The accompanying chart, prepared by S. C. Hollister from data compiled by U.S. Bureau of Labor Statistics, U. S. Office of Education, A.S.E.E. and Engineering Manpower Commission of E.J.C., gives a summary of the present engineering manpower situation. It shows the number of graduates from this country's engineering colleges for each year since 1940, and the effect of Selective Service on engineering education during the war. The return of veterans from World War II, through the operation of the G.I. bill, increased the number of engineers graduated from the schools up to and including this past June.

A survey of industrial and governmental need for civilian engineers indicated that 80,000 engineers were needed by June 1 last (with an estimated 15,000 added to be used by the services in uniform and the total is 95,000 as shown on the chart). The class of 38,000 was all that was available to meet this year's needs. Half of these are or soon will be committed to the armed forces. Next year's need is not likely to be less than last year's. At best, it will not be possible to meet the need from the supply of graduates now expected from the colleges, because this supply will be less than half enough. Before the war, nearly 6 per cent of the boys graduating from high school entered engineering colleges. Now the rate has dropped to 4.8 per cent. About 10 per cent would be needed to meet peace time civilian needs alone.

MAINTENANCE PROBLEMS TO BE DISCUSSED

The third Plant Maintenance Conference will be held concurrently with the Plant Maintenance Show at Convention Hall, Philadelphia, Jan. 14-17. The schedule calls for 34 separate discussions, six general conferences, 27 sectional meetings and the annual banquet. General topics include: Maintenance Costs; Inspection Methods and Records for Preventive Maintenance; Lubrication; Maintenance in Oil Refineries, etc. Approximately 200 companies will display products and services necessary for maintenance. Both conference sessions and exhibits will place the principal stress on preventive maintenance.

NEW CHEMICAL ENGINEERING JOURNAL

As a result of the establishment of contacts with chemical engineers and their institutions in England, France, the Netherlands, Belgium, Switzerland, Italy, and the Scandinavian countries, Pergamon Press Ltd. is publishing an international journal titled, "Chemical Engineering Science." This new journal will run original research work on chemical engineering. Articles will be printed in either English, French, or German and each paper will be preceded by a summary in two languages (one of them will be English). All articles must be accompanied by a list of references and the literature quoted in the text. Symbols accepted by the International Union of Chemistry and by the American Institute of Chemical Engineers will be used.

The first issue of the paper, which for the time being will be issued once every two months, appeared in October, 1951. The editorial office is located at 2, 3, and 5, Studio Place, Kinnerton Street, London, S.W. 1.

The Editorial Board consists of: Prof. J. Cathala, Universite de Toulouse; Prof. M. B. Donald, University College, London; Prof. F. Giordani, University Naples; Prof. A. Guyer, Federal Technical High School, Zurich; Prof. W. L. de Keyser, Universite Libre Bruxelles; Dr. D. W. van Krevelen, Central Laboratory of the Staatsmijnen, Limburg; Prof. S. G. Terjesen, Technical University Trondheim.

$1,000,000 FOR MIDWEST MINERAL EXPLORATION

The search for new reserves of strategic and critical minerals under the Interior Department's Defense Minerals Administration's financial assistance program is gaining momentum in the Upper Midwest.

Mining operators in three States—Wisconsin, Michigan and South Dakota—to date have signed ten Government exploration contracts involving nearly a million dollars, according to Paul Zinner, Bureau of Mines Region V regional director.

Of the $945,035.75 now being spent for mineral exploration in these states, the Government is contributing more than one half of the cost or $524,493.66 and private industry, $420,542.09. This total expenditure is 11.7% of the $8,014,846 invested in 128 mineral exploration contracts throughout the country (as of Sept. 10, 1951) entered into between the Government and nine operators or lessees since the program began last April.

Under the terms of the Defense Production Act of 1950, the Defense Minerals Administration is empowered to provide financial assistance for mineral exploration projects on a "matching fund" basis. The Government contributes 90% of the cost in exploring for new sources of mica, beryl, tin, tungsten, columbium and tantalum, and 50%, for copper, lead and zinc. Private industry pays the rest.

A.S.T.M. SCHEDULES MEETINGS IN 1952

The American Society for Testing Materials 50th Anniversary Meeting will be held in New York, June 23-27, 1952, at the Hotels Statler and New Yorker. It is expected that there will be groups of papers and symposia on the following subjects: synthetic fibers; adhesives; plastics; continuous analysis of water; fatigue, effect of temperature; fretting corrosion, etc. The annual meeting will also feature an exhibit of testing apparatus and related equipment and there will also be a photographic exhibit.

A feature of the 1952 spring meeting of the A.S.T.M. to be held during the week of March 3 at the Hotel Statler in Cleveland, Ohio, is a symposium on testing metal powders and metal powder products. There will be several technical papers by leading authorities in this field.

AWARD WON BY PHILLIPS PETROLEUM

Phillips Petroleum Co. will receive the 1951 award for chemical engineering achievement given annually by Chemical Engineering, a McGraw-Hill publication. Present plans call for the award to be given at a dinner at the Waldorf-Astoria Hotel during the week of the Annual Exposition of Chemical Industries.

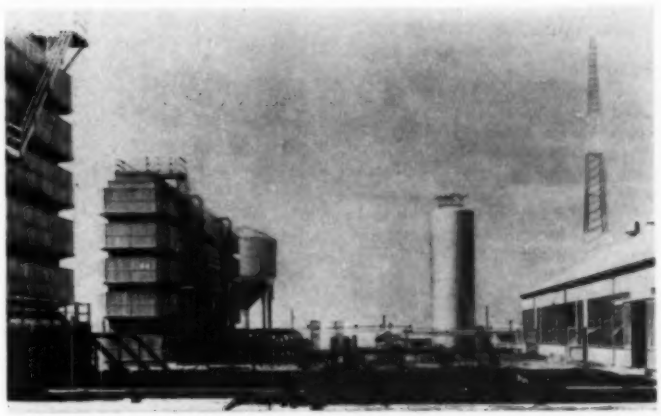
The Phillips company was given the award for its commercial development of high abrasion carbon black and its major contributions to the development of cold rubber.

The awards committee headed by A. H. White, professor emeritus of chemical engineering at the University of Michigan, was comprised of 70 chemical engineering educators in the United States.

"COALS" CONTINUED IN OHIO STATE SERIES

"Further Studies of Ohio Coals and Oil Shales" is the title of a 70-page booklet issued by the College of Engineering, Ohio State University, Columbus, as Bulletin No. 143. It consists of three parts: Part I. Some Studies of Ohio Coals and Oil Shales by Peter O. Krumin; Part II. Ohio Coals by William H. Smith, and Part III. Ohio Shales and Cannel Coals by Charles H. Bowen. The price of the pamphlet is $1.00.

HARCO'S CATHODIC PROTECTIVE SYSTEM



The Harco Corp. has installed a specially engineered cathodic protective system in a Midwestern natural gas pumping station to eliminate corrosion of underground pipes. More than 45,000 sq. ft. of metal pipe surface is located underground in this pressure boosting station. Soil conditions in this area are such that unprotected metallic pipe lasts on an average of from nine to eleven years. Natural gas is received by the station through large diameter lines at approximately 400 lb./sq.in. pressure. In the compression station (shown at right), this natural gas is boosted to a 700 lb./sq.in. pressure and piped for use both domestically and industrially.

The cathodic protection system virtually eliminates pipe corrosion. Engineers took into consideration soil conductivity, moisture content, soil and water chemical characteristics, temperatures, dissimilar metals, etc. Three electrode beds utilizing a total of 80 National Carbon graphite anodes were prepared, and carbon backfill material was specified. General Electric rectifiers were installed. A direct current impressed on the anodes radiates through the backfill material and soil to the metal pipe surface to prevent corrosive electrochemical action.

TITANIUM PRODUCTION AT HENDERSON STARTED

First actual production of titanium metal at the newly constructed Henderson (Nev.) plant of Titanium Metals Corporation of America occurred recently. This company, owned jointly by National Lead Co. and Allegheny Ludlum Steel Corp., will expand output rapidly until an initial production goal of ten tons per day is reached late next year. This will be equivalent to eight times the present world production of titanium metal.

The Henderson project was announced in August following the signing of a letter of intent by the General Services Administration, an agency of the United States Government. Leases were secured on major components of the $150,000,000 former Basic Magnesium, Inc. plant built by the Government during World War II, and 151,000,000 kw. hr. of power were allocated from nearby Hoover (Boulder) and Davis dams by the Colorado River Commission.

Outstanding physical properties of titanium metal and titanium-base alloys have brought about an urgent demand for both military and atomic energy uses.

DISTILLATION RESEARCH

Progress is reported by Walter E. Lobo, chairman of the Research Committee of the American Institute of Chemical Engineers and director of chemical engineering division of the M. W. Kellogg Co. in the selection of items to be studied in a proposed research program on bubble-plate efficiency fostered by the A.I.Ch.E. According to Mr. Lobo, the committee has made a survey of all research institutions to determine interest, experience, facilities, and manpower to undertake this study, and three universities have been recommended to carry out various phases of the over-all program.

The Research Committee was appointed in July, 1950, by the Council of the Institute "to foster research projects in chemical engineering which by their scope, complexity, or general nature, were such that no single institution or company could afford to institute a comprehensive planned research program."

It was the aim of the Institute in forming this committee to choose such projects of broad interest which would attract the interest of many large and small industrial concerns. The committee has been studying the necessity of a research program in bubble-plate efficiency since then, and has developed a basic program of research on effect of tray design and system properties on tray efficiency both in fractionation and absorption.

According to Mr. Lobo the program, as it is now set up, calls for variations in column size and tray spacing with a wide range of operating pressures and systems. This will permit "thorough evaluation of the individual effect of the gas and liquid phases on the efficiency of separation." "If the program is accepted," said Mr. Lobo, "this will be the first time that such a comprehensive study is undertaken in chemical engineering and the results will be beneficial to all industries in the chemical process field."

According to the President of the Institute T. H. Chilton, activation of the experimental work now "awaits only final approval of the Research Committee budget by the Council and active solicitation of the funds for its operation from interested industrial organizations."

FLUOROCHEMICALS UNIT BY MINNESOTA MINING

Minnesota Mining and Manufacturing Co. opened a full-scale operation at St. Paul, Minn., of the world's first unit for making fluorochemicals in semicommercial quantities electrochemically. The production is based on a process developed and patented by J. H. Simons of the University of Florida. The fluorochemicals serve as a new group of chemical intermediates for use in the manufacture of other products.

The new quarter-million-dollar unit, located near Hastings, Minn., provides 60,000 sq.ft. of floor space. It includes room for further facilities for the fluorochemical project, it was announced. Production facilities include specially designed electrolytic cells and auxiliary equipment.

These new facilities make possible the supply of ton-lots, and larger, of special purpose fluorochemical materials among which are reactive compounds such as completely fluorinated acids and their derivatives, and unreactive compounds including inert perfluoro liquids and gases. The liquids include both perfluoro tertiary amines and perfluoro ethers. Among the first of the compounds to be produced will be trifluoroacetic acid and heptafluorobutyric acid.

ENGINEER SHORTAGE DRAMATIZED ON RADIO

A special program dramatizing the nation's critical need for engineers will be featured on "Adventures in Research," the Westinghouse Electric Corp's radio science show. Entitled "Supermen Wanted," the transcribed public-service feature will highlight the role of the engineer in the technological growth of the nation and emphasize the present critical shortage of technical manpower.

"Supermen Wanted" will be broadcast during the week beginning Sunday, Nov. 25. It is designed to aid in the educational campaign now being undertaken by the Engineering Manpower Commission of the Engineers' Joint Council to bring the manpower shortage to the attention of the American people.

SHELL CHEMICAL BUILDS SULFUR RECOVERY PLANT

In a move aimed at alleviating the critical shortage of sulfur and its compound, sulfuric acid, Shell Chemical Corp. will add to its Houston operations a unit for recovering sulfur from waste refinery gases, it was announced last month by W. P. Gage, vice-president. Output of the new unit will be sold for conversion to sulfuric acid.

The new sulfur recovery unit, certified by the Government as a necessary defense project, will be constructed by the Ralph M. Parsons Co., of Los Angeles. Operation is expected by mid-1952. In the recovery process, waste refinery gases, containing hydrogen sulfide, carbon dioxide and a small percentage of light hydrocarbons, will be burned and catalytically converted to sulfur at an annual rate in excess of 13,000 tons.

ALGAE PROJECT BY CARNEGIE INSTITUTION

The Carnegie Institution of Washington recently announced that it is continuing a project at Arthur D. Little, Inc., consulting research and development organization of Cambridge, Mass., for the development of a commercial process for the culture of rapidly growing algæ, which may become a useful food source. During the past six months a pilot plant with a total growing area of 1200 sq.ft. has been constructed and put into operation. In one unit of the pilot plant a suspension of the green, unicellular alga *Chlorella* is exposed to sunlight by being pumped continuously through a large transparent plastic tubular channel; and in a second unit the algal suspension is circulated in a trough with a transparent plastic cover. Continuous growth has been maintained and material harvested daily.

This pilot plant is part of a general program that has for its purpose finding out whether large-scale algal culture is feasible technically and economically as a means of utilizing solar energy.

BENZENE PRODUCED BY STANDARD TO EXPAND

Standard Oil Company (Ind.) has started commercial shipment of benzene produced from petroleum in the new benzene plant at its Whiting (Ind.) refinery. Benzene is in strong demand as a result of the defense program, according to Dr. M. G. Paulus, vice-president in charge of manufacturing. It is used extensively by the synthetic rubber, chemical, and other industries.

The present Whiting plant will produce about 11,000,000 gal. of benzene per year. Expansion, scheduled for completion in the second half of 1952, will increase the capacity to 16,000,000 gal. per year.

Most of Standard's benzene production will be sold to the chemical industry under long-term contracts. Last year a Standard subsidiary, the Pan American Petroleum & Transport Co., started commercial shipments of benzene produced from petroleum at the Texas City (Tex.), refinery of Pan American Refining Corp. Indoil Chemical Co., another Standard subsidiary, has also been producing benzene on a small scale for the last year.

(*More News on page* 30)

Wiggins Gasholder does 7 years' work in 11 months!

See us at the General American Display at the 23rd Exposition of Chemical Industries, Booths 285 and 287

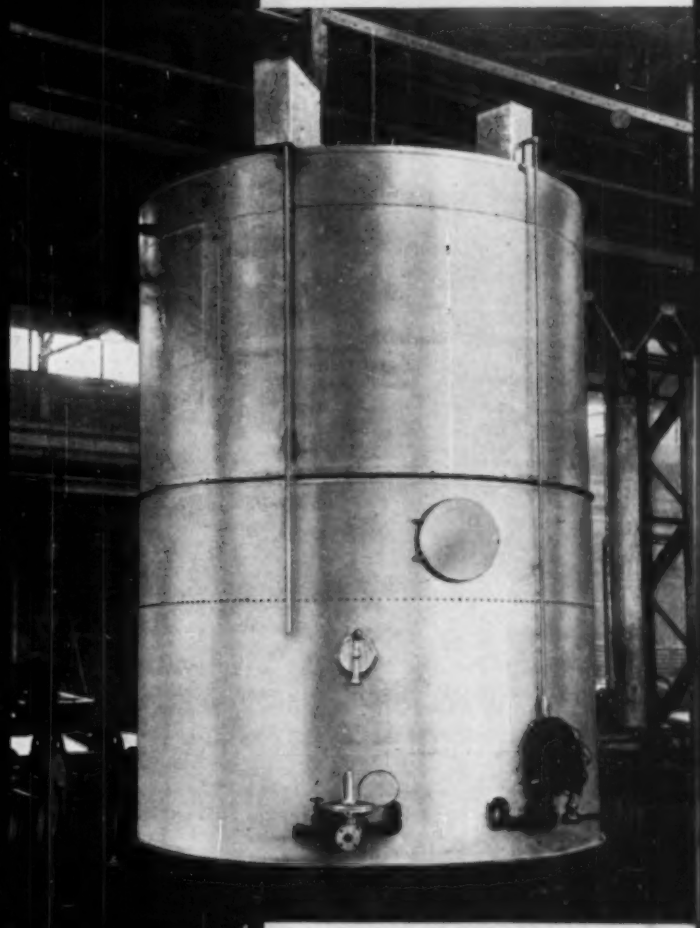
Pilot gasholder stores coke oven gas for nationally known steel maker. *Dry seal proves thoroughly effective!*

March 13, 1950, a pilot plant test was begun to determine suitability of the Wiggins neoprene dry seal in storing debenzolized coke oven gas. Automatic controls were installed which filled and emptied the gasholder every hour. This was the operation over the first several months. During the remaining period, this cycle was alternately speeded up and slowed down. On February 13, 1951, this Wiggins Gasholder test was completed —after 11 months and 2,650 cycles— roughly equivalent to 7 full years of operation at one cycle per day!

During the entire test period coke oven gas was in continuous *direct contact* with the seal fabric. Temperatures in the gas space ranged from over 100° F. to below 0° F. During much of the test, inside surface of seal was wet with condensate. All these combined to give as severe a test as anything that could be expected.

THESE WERE THE RESULTS:

- Air side of *dry seal* in original condition.
- Neoprene coating on gas side flexible and resilient—unaffected by chemical action. No hardening or cracking.
- All seams gas-tight. NO HARMFUL EFFECTS TO DRY SEAL.



Test Wiggins Gasholder—11' 5" diameter; 16'0" high. Maximum movement of piston—10' 10 11/16".

Wiggins is the ONLY gasholder using an absolutely dry, frictionless seal. No water, tar or grease. No weather worries, operating costs or maintenance problems. No replacement of sealant. Write for new BULLETIN WG-22 . . . or refer to Builders' Committee Report (May, 1951) American Gas Association.

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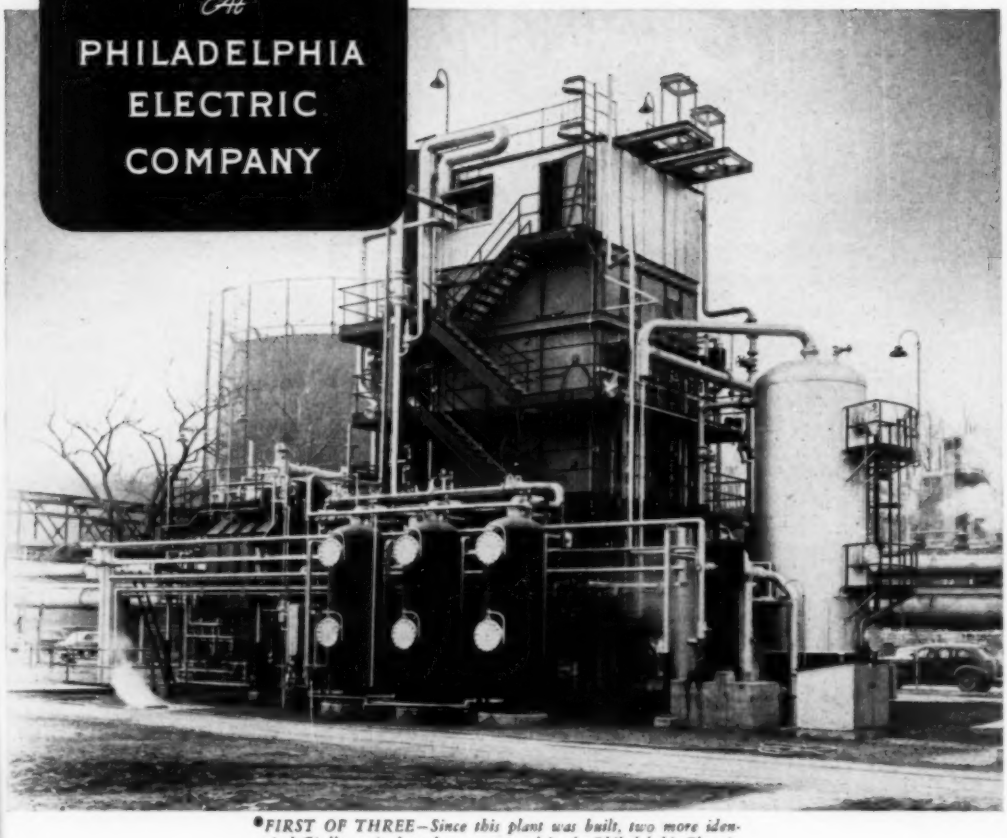
At

PHILADELPHIA ELECTRIC COMPANY



FIRST OF THREE—Since this plant was built, two more identical Girdler units have been contracted for by Philadelphia Electric.

Girdler plant makes "carrier" gas

INCREASED DEMANDS for fuel gas by customers of Philadelphia Electric caused the company to install a plant to produce "carrier" gas. This gas is mixed with other gases so that the finished gas is exactly right for the customers' needs.

The problem was solved by catalytic cracking of the natural gas in a Girdler Gas Plant. This unit produces a carrier gas, of very precise composition, which meets Philadelphia Electric's high standards. The plant was built outdoors—saving the cost of a building—and it is practically automatic in operation. Steam is generated from the waste heat in the flue gas.

Flexibility is one of the major advantages of this plant. In emergencies, when the supply of natural gas is insufficient, propane can be reformed and oil used as a fuel. The use of Girdler catalyst insures maximum gas production at the lowest possible cost.

Girdler's experience in gas processing can help you, too. We design and build plants for the production, purification, or utilization of many chemical process gases; purification of liquid or gaseous hydrocarbons; manufacture of organic compounds.

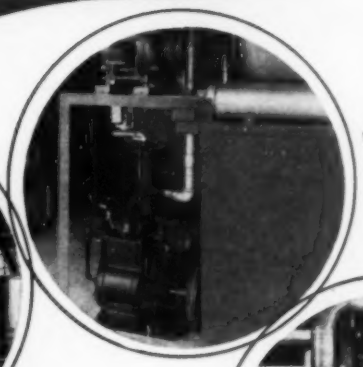
* * *

Write for bulletin G-35. The Girdler Corporation, Gas Processes Division, Louisville 1, Kentucky.

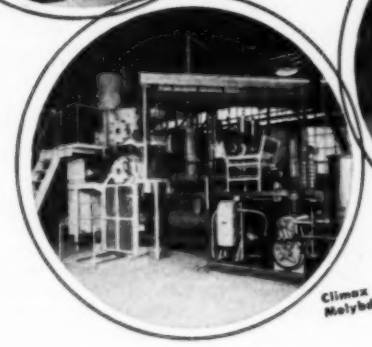
THE GIRDLER CORPORATION
Gas Processes Division

Seen in the Best Circles!

Sylvania Electric Products

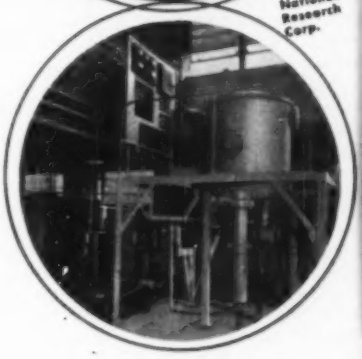


Proctor & Schwartz



Climax Molybdenum

Distillation Products Industries



National Research Corp.

- **Sylvania Electric Products is producing super-size TV picture tubes in this giant merry-go-round.**
- **Climax Molybdenum uses this high vacuum furnace for metallurgical research.**
- **Proctor & Schwartz and Dry-Freeze Corporation have developed a process for freeze-drying materials which would otherwise be damaged by high temperatures.**
- **Putting a thin layer of metal on cellophane is the job of this vacuum coating machine made by Distillation Products Industries.**
- **Metals are melted and cast to a new high standard of quality in this National Research Corporation vacuum furnace.**

Each of these installations is different: each is designed to perform a highly specialized task. But all have this in common — all use KINNEY HIGH VACUUM PUMPS to get down to low absolute pressures fast and dependably.

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Kinney VACUUM PUMPS

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MARGINAL NOTES

News of Books of Interest to Chemical Engineers

A Man of Purpose

Herbert H. Dow, Pioneer in Creative Chemistry. Murray Campbell and Harrison Hatton. Appleton-Century-Crofts, Inc., New York, N. Y. (1951) 168 pp. $3.50.

Reviewed by F. J. Van Antwerpen, Editor, Chemical Engineering Progress.

REVIEWING the book on the life of a man is usually easy provided the man was merely prominent. If the prominence came from a spirit which was pioneering, creative, and which effected events instead of being affected by them, the reviewer (but even more so the author) is called upon to explain something of the personality, something of the compulsion which kept the man steadily on his purposeful road.

After reading the life of Herbert H. Dow, I was convinced that the enviable thing in his life was not so much the fact that he was the founder of the Dow Chemical Co., which today is our fourth largest chemical company selling more than $200,000,000 worth of chemicals a year, but that he was endowed with so much courageous purpose. Founding Dow was an important achievement and it was not an easy achievement. But one must look for some other lesson, some other key, for benefits to be obtained from a close study of his accomplishments.

One of the first things that struck me in reviewing this book was Dow's courage, and it is a courage which is fast escaping from the American scene. With no industrial experience behind him and only a year of teaching at the Huron Street Hospital College in Cleveland, he set up a shoestring company consisting of *himself and three other men*. This first venture of his, christened the Canton Chemical Co., made ferric bromide by extracting bromine from the brine found in such quantities under Ohio and Michigan, and blowing it over iron. Only a few hundred dollars were involved in the company, and it failed in less than a year. However, Dow had such faith in his process that he immediately went to work to set up another company. He did this in a matter of four months and proceeded to work with money scantily supplied by his backers until a corporation was formed having 10,000 shares at a $10 per share value. Dow, in the new setup, was general manager. The company—The Midland Chemical Co.—was successful, it made money and paid dividends to its backers. However, Dow was primarily a pioneer and at the age of 29 found himself stymied in development work. He left Midland and started another company in Navarre, Ohio. This was called the Dow Process Co., and Dow was trying to electrolize salts to make chlorine for processing into chloride of lime for bleach. His total capitalization at the time was about $16,000 and after a half year at Navarre, he went back to Midland. Two years later the company was recapitalized at $200,000, the name changed to the Dow Chemical Co. Later the new company was to take over the Midland Chemical Co. which Dow had founded as his second venture. Dow at that time was 31 years old and had for seven or eight years stubbornly fought out the battle of producing chemicals from natural brine, and salts. He had formed four companies though only one actually was a failure.

But the important item in Herbert Dow's life at this time and sympathetically brought out by the authors of the book, was his spirit of continuously trying, never giving up, never losing faith in either himself or his processes and stubbornly sticking to his ideas and guaranteeing by personal attention, their success.

Explosions, failures of backers to come through with promised support, the loss of control of companies he had set up, did not deter him. There was in the man a compulsion to go further, do more things, to grow and to maintain a faith in American enterprise. If the book has any fault it is that clues to his complete personality must be found in his industrial work. One must practically guess that he was a religious man. Two months after he arrived in Midland for the first time, the reader notes that he took a class of boys in Sunday school and for years, at his own expense, he kept the churches of Midland painted regardless of denomination.

But even though his personal life is not well documented in this book, he must have been a man of great sensitivity and loyal not only to his own ideas and to himself, but also to those who were with him. For instance, one reads that Dow thought up the idea of having one of his workmen, who had grown old and infirm in his service and was due for retirement, sit on a stool at the gates of the plant and merely greet fellow workmen as they passed in or out. "The man sat there for years feeling himself still to be an important cog in the company's operations, which was exactly what Herbert Dow felt he was entitled to feel."

Dow also had one of the first employee profit-sharing arrangements in American industry and one of his last acts was to call in the foreman of an old employee who had been with him from the beginning and who had now grown old, and say to the foreman, "I don't want anything ever to happen to hurt his feelings." Such glimpses of the spirit of Herbert Dow are not too common in the book. It is a pity for he must have had a great capacity to love his fellowmen.

That he was a man of courage we know from his early attempts to begin his business, but once having arrived at success he was not averse to backing it up with all the finances at his command. Dow fought to hold his market on bleach when the British, as a competitive move, reduced the price from $3.50/cwt. to 88½ c. In meeting this challenge Dow immediately signed away his 1904 output at 86 c. and though it broke up the war it cost his company some $90,000 of income.

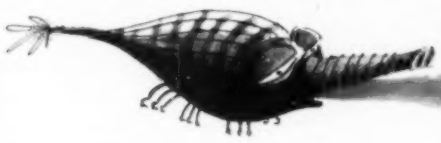
It was essentially the same with the Germans on bromine when he successfully battled the cartel Die Deutsche Bromkonvention.

So, in reviewing this book it would be easy to stress Dow's successes in extracting chlorine and bromine from brine and sea water, synthesizing indigo, in producing magnesium, or making phenol on an industrial scale. These are, to be sure, major achievements and yet as indicated at the beginning of this review, the important thing is to understand why, and in some way or other to indicate that the life history of Herbert Dow is a triumph of the will to succeed. If such industrial miracles are to occur in the American scene, the will to succeed must be kept alive.

This book was presented to me with a friendly note from Leland L. Doan, president of the Dow Chemical Co. Perhaps he expressed it best of all in a portion of the note which said, "These (Dow's) qualities carried him to high personal achievement. But it is a type of achievement it seems to me, which is possible only to free men."

Corrosive fumes...

Salt air...



Hot air...

Moist air...

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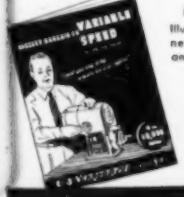
Newest and most convenient power drive at popular low price. Increases output of motor driven equipment. Performs the duties of a motor, speed changer, cone pulleys, rheostat or controller and gear box. Just turn a dial and get any speed instantly. 10 to 1 speed range. Very compact, light weight. Asbestos-protected windings. Horizontal and upright types.

4 to 10,000 RPM, BY DIAL CONTROL



Request Bulletin

Illustrates, describes many new exclusive features and various models.

MOTORS

U. S. Electrical Motors, Inc. CEP-11
200 E. Slauson Ave., Los Angeles 54, Calif.
or Milford, Conn.

Send VA Varidrive Motor Bulletin ☐
Other Bulletins: Unicased Motors ☐
Syncropear Motors ☐

Name_____

Company_____

Address_____

City Zone State

(*News continued from page 24*)

VINYL TANK FOR FLUOSILICIC ACID

A special rigid plastic tank to hold hydrofluosilicic acid, a highly corrosive substance used to fluorinate the water supply from Avon Lake, Ohio, has been constructed by the sales service laboratory of B. F. Goodrich Chemical Co. Above examining this container are: C. E. Parks, right, manager of the company's sales service laboratory, and Paul McCampbell, Avon Lake's superintendent of water works.

Material for the new tank is Geon 404, a rigid vinyl plastic recently introduced by the Goodrich company. The container approximately 16 in. in diameter and 26 in. tall, will hold about 20 gal. of hydrofluosilicic acid. All nuts, bolts, and studs for the tank are also made of the rigid plastic material. No metal is used.

DAVISON TO MAKE BUTADIENE CATALYST

The Davison Chemical Corp. has contracted with the Reconstruction Finance Corp. Office of Rubber Reserve to produce a tantala-silica gel catalyst for deriving butadiene, needed in large quantities in the manufacture of synthetic rubber, from ethyl alcohol and acetaldehyde. The material will be delivered to the Koppers Co. and Carbide and Carbon Chemicals Co., producers of butadiene, as agents for R.F.C.

In 1944 production of butadiene by the alcohol process reached 700,000,000 lbs. In the current program, it is estimated that more than 20 per cent of the butadiene will be from alcohol.

In the process, ethyl alcohol is mixed with acetaldehyde, which is obtained by dehydrogenation of ethyl alcohol. The mixture is passed over the tantala-silica gel catalyst to form butadiene and by-products such as hydrocarbons, aldehydes, ketones, esters, ethers and alcohols.

The catalyst is 2% tantalum pentoxide and 98% silica gel. The gel in the catalyst is used for the condensation of acetaldehyde to crotonaldehyde. The crotonaldehyde is an intermediate product which is reduced to butadiene by the tantala in the catalyst, with the ethanol acting as a hydrogen donor.

WHAT IS A SCIENTIST

General Aniline & Film Corp., recently decided to find out what a typical scientist is like. General Aniline, with a fair representation of scientists among its 9,000 employees conducted a survey among members of its own research staff, distributed a questionnaire with 20 main questions and a like number of subordinate queries. The entire quiz was anonymous.

Cooperation by these researchers in a bit of research about themselves was given—90% responded—and requests for the findings have been numerous.

The corporation has issued a description of the typical research man based on its findings. Commenting upon the average age at "just under 35," Henry B. Hass, manager of research and development for General Aniline, said that this probably reflects the American average.

Included in the quiz were chemists, who comprise the vast majority of General Aniline research people, engineers and physicists. About 45% of them are Ph.D.'s; 43% B.S.'s, and 12% M.S.'s.

Here's the typical American scientist, according to the survey:

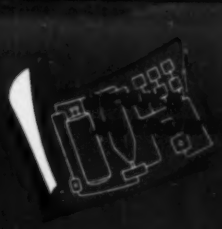
He is just under 35 years of age, 5 ft. 9 in., weighs about 160 lbs., blue or brown-eyed with brown hair, is married and has one or two children, whose names are most likely to be John, William, James or Robert, Susan, Janet, Carol or Mary. He holds at least a B.S. degree and the chances are he's a Ph.D. He personally holds or shares with associates about three patents and his name is on two patents pending. He understands from one to six foreign languages.

The American scientist as measured by General Aniline standards sleeps about seven hours a night, is more apt than not to be a church-goer, attends the movies more frequently than the concert, tunes in to his radio about 8½ hrs. a week and to his T.V. set about 7 hrs. He keeps up with the news of the day by regular readership of newspapers and magazines, and reads about 24 books a year, about 10 of which are related to his work.

The General Aniline scientist who is married, owns his own home with a value averaging about $18,000 and has an equity of $9,000 in it. He participates in community and civic affairs and to a lesser degree in the activities of fraternal organization.

He plays the piano or some other musical instrument, and enjoys a wide variety of sports and hobbies—as a golfer he shoots around 106 for 18 holes, but some of his associates claim a par of under 80. Bowling is his favorite indoor player-participation sport and he has a slight preference for checkers over chess; tennis has a slender edge over baseball. He enjoys swimming most in the field of recreation as exercise, but some of his associates go in for mountain-climbing, trout or just plain fishing, or hunting. As a hobbiest, he covers a wide field.

The corporation's research man is contented with his work, discusses it with his wife and if he had it to do all over again, he would still be a scientist. He and his associates are divided on the shape of world affairs, but they are agreed that we face a third world war, at least in their life-time if not in the next five years.



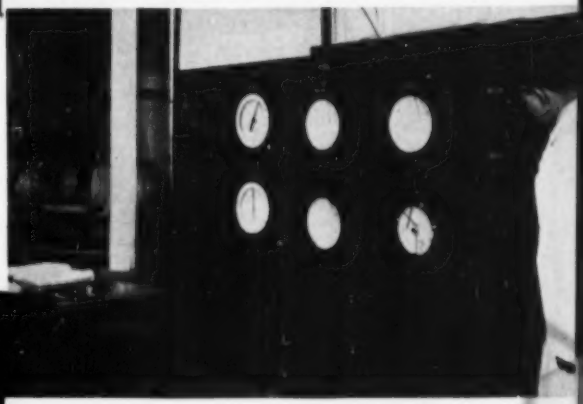
THE MODERN APPROACH TO *Drying Control*

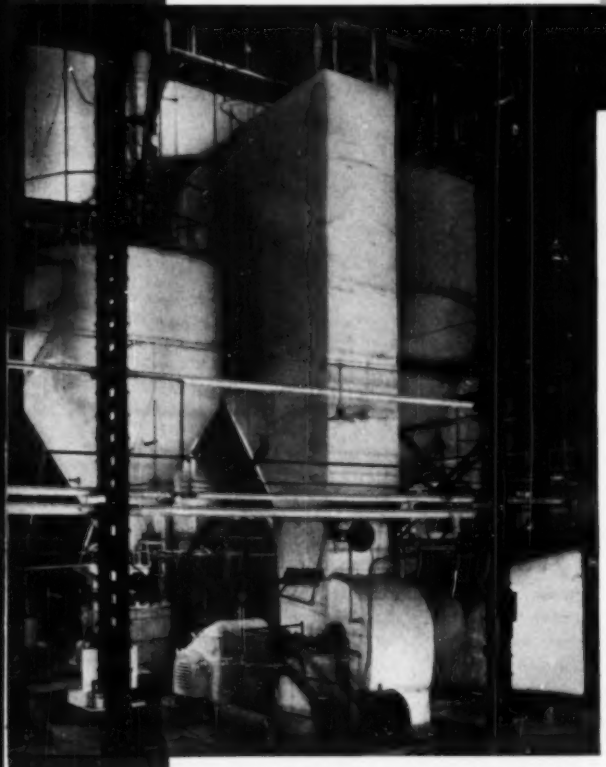
BROWN INSTRUMENTATION

. . . is patterned to the exact requirements of individual plants and processes.

. . . is the result of engineering and application know-how, with one responsibility from sensing elements to control valves.

. . . is backed by a nation-wide field engineering and service organization.





Pictured is a gas-heated Swenson spray dryer in a chemical processing plant. The use of Brown automatic controls precludes the possibility of under- or over-drying by enabling an operator to: (1) control final product moisture through control of dryer outlet temperature, (2) regulate the pressure of volume and spray, and (3) control the temperature to the dryer.

TYPIFYING the hundreds of units that annually are yielding thousands of tons of dried chemical products is the Swenson chemical spray dryer installed at the Quebec plant of Distillers Limited.

With the help of modern Brown instrumentation, this dryer provides a new high in operating ease and efficiency. Uniform moisture content of product is obtained *automatically*, thus preventing variation in quality or deterioration of the dried material in storage.

From a centrally located panelboard of Brown instrumentation, the entire drying operation can be viewed through continuous recording and controlling instruments . . . each phase accurately recorded, rigidly controlled.

When looking for recording and controlling instruments for your drying operation . . . whether it be spray, cabinet, drum, vacuum or other . . . *consider first:*

- **The Brown know-how developed through many years of application experience in the industry.*
- **The completeness of the Brown modern approach—recorders, controllers, panelboards, valves and all accessories.*

Call in our local engineering representative for a detailed discussion of your process requirements . . . he is as near as your phone. Offices in more than 80 principal cities of the United States, Canada and throughout the world.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 4427 Wayne Ave., Phila. 44, Pennsylvania.

MINNEAPOLIS
Honeywell
Brown Instruments

WHY ABBOTTS DAIRIES CHOSE A REFRACTORY FORTIFIED WITH ALCOA ALUMINA

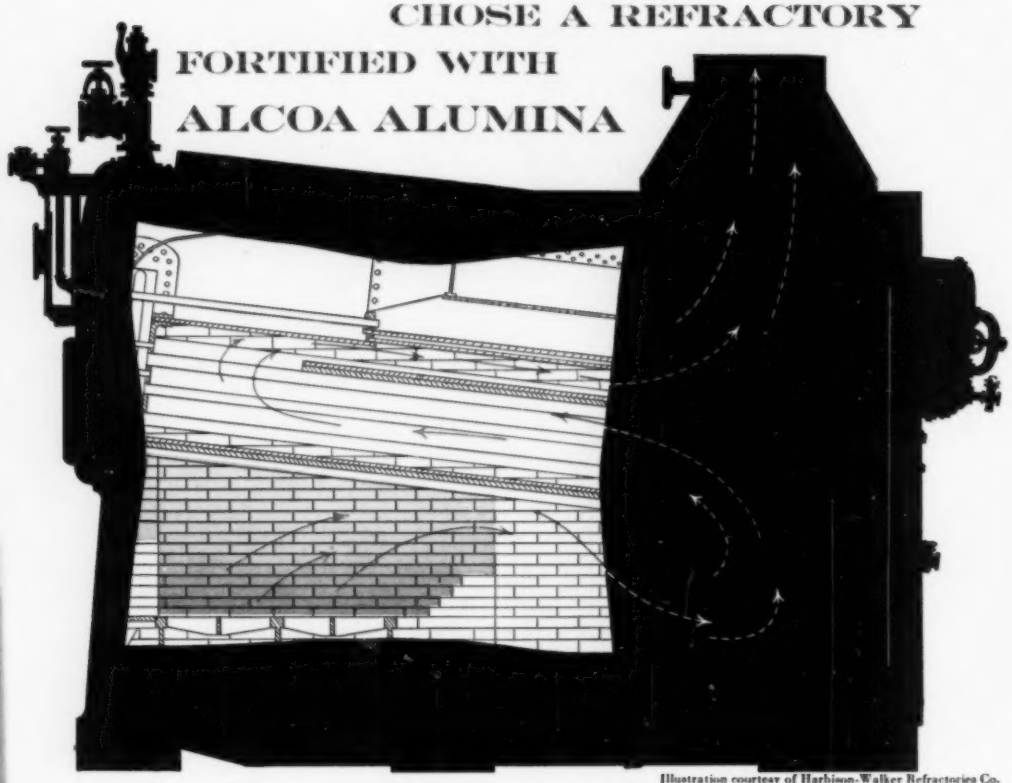


Illustration courtesy of Harbison-Walker Refractories Co.

Horizontal type boiler at Cameron creamery uses Korundal 90% ALCOA Alumina-content brick to resist extreme slagging by high iron oxide coal ash at unusually high temperatures. Korundal is used to a height of 30" above grates in side wall and for complete 9" facings of bridge and front walls.

REFRACTORY BRICK must prove itself the hard way at Abbotts Dairies, Bruce and Cameron, Wisconsin.

Six months of the year, round-the-clock, white-hot flames and molten slag torture boiler furnace walls in an extremely severe test for the best refractories available.

In 1944, Korundal, a 90% ALCOA Alumina-content brick, was installed experimentally in one of the Bruce creamery boilers. After a convincing demonstration of several years, high alumina-content Korundal was installed in Abbotts Cameron creamery boiler furnace, because down-time and repairs cost more than good refractories.

Refractory brick made with ALCOA Alumina offers *you* these money-saving advantages:

- **Strength and stability under load at high temperatures.**
- **Resistance to spalling, abrasion and fluxing at high temperatures.**
- **Resistance to corrosive slags and fumes.**
- **Low porosity.**
- **Negligible shrinkage.**

You can buy refractory brick and other shapes, containing various percentages of ALCOA Alumina to meet your requirements, from leading manufacturers. We'll gladly refer you to dependable sources of supply. Write to: ALUMINUM COMPANY OF AMERICA, CHEMICALS DIVISION, 605L Gulf Building, Pittsburgh 19, Pa.

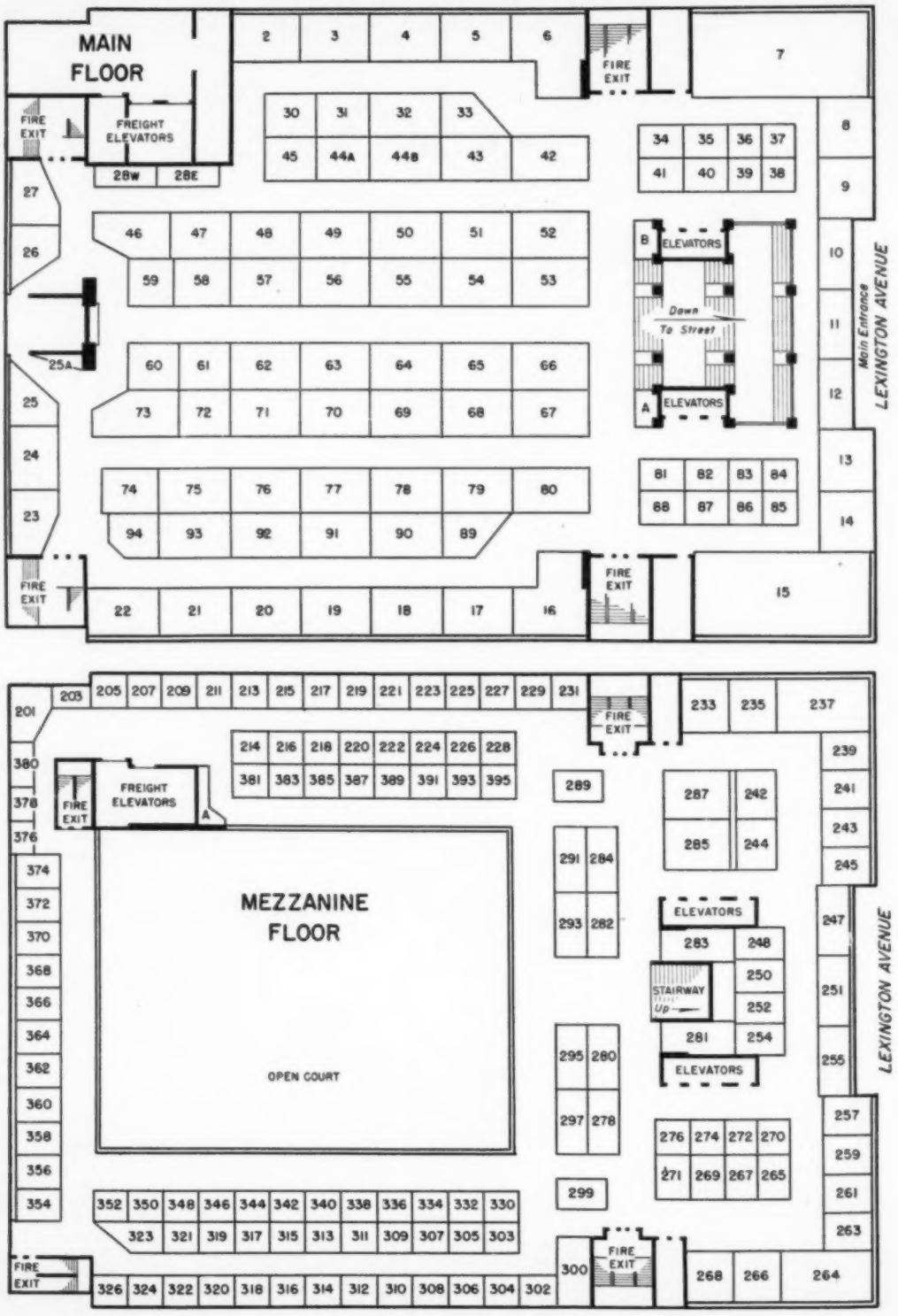
Alcoa Chemicals

ALCOA

ALUMINAS and FLUORIDES

ACTIVATED ALUMINAS • CALCINED ALUMINAS • HYDRATED ALUMINAS • TABULAR ALUMINAS • LOW SODA ALUMINAS ALUMINUM FLUORIDE • SODIUM FLUORIDE • SODIUM ACID FLUORIDE • FLUOBORIC ACID • CRYOLITE • GALLIUM

SWENSON
PFAUDLER
23rd EXPOSITION OF
CHEMICAL INDUSTRIES
GRAND CENTRAL PALACE
November 26—December 1
KARBATE
STANDARD PIPE
Lapp
MILTON Roy
MAURICE A. KNIGHT
AKRON OHIO
KNIGHT-WARE
FANSTEEL
HARDING
The U. S. STONEWARE Co.


MAIN FLOOR
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FREIGHT ELEVATORS
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81 82 83 84
88 87 86 85
B ELEVATORS
Down To Street
A ELEVATORS
Main Entrance
LEXINGTON AVENUE
MEZZANINE FLOOR
OPEN COURT
A
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ELEVATORS
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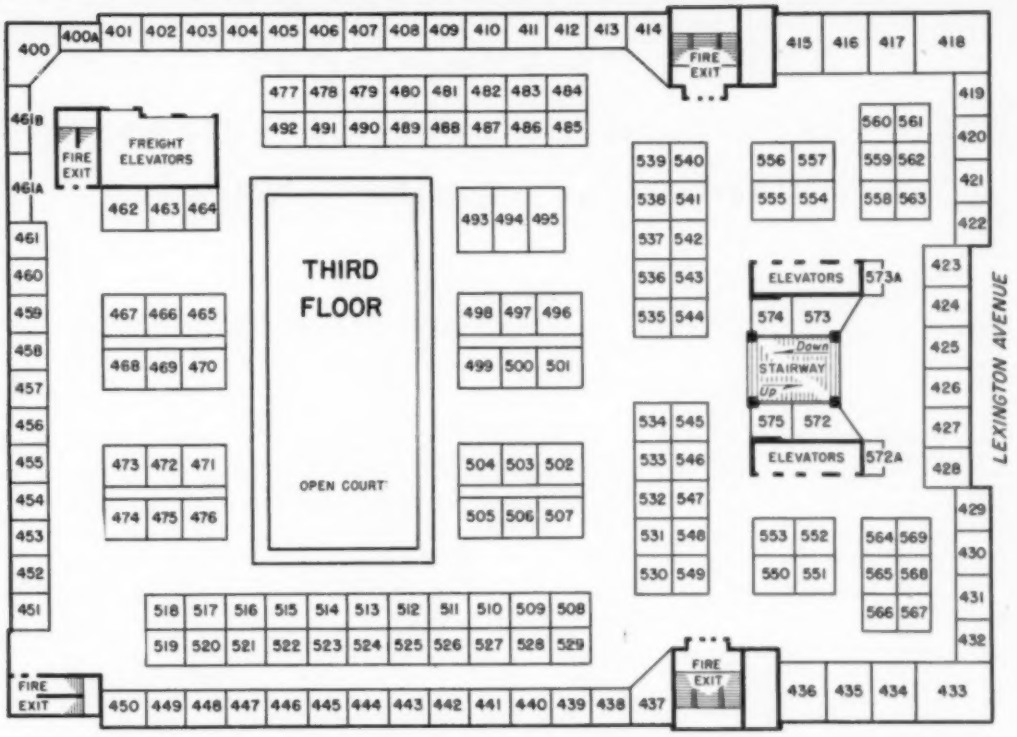
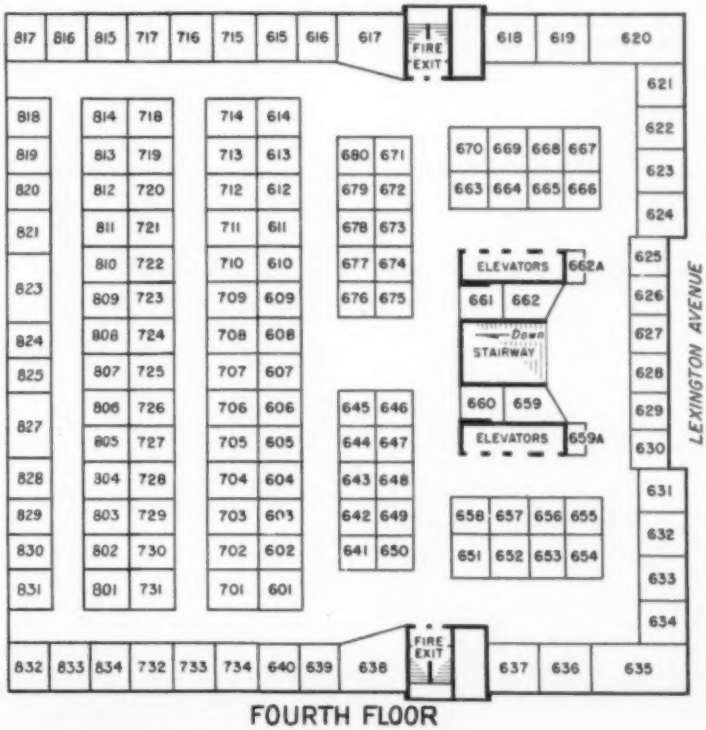




FOURTH FLOOR

FLOOR PLANS OF GRAND CENTRAL PALACE

EXPOSITION HOURS:

Doors open Monday, Nov. 26 at 2 P. M. All other days' opening 11 A. M. Closing 10 P. M., except Wednesday, Nov. 28, and Saturday, Dec. 1 when closing time is 6 P. M.

LIST OF EXHIBITORS

23RD EXPOSITION OF CHEMICAL INDUSTRIES

November 26 — December 1, 1951

Booth No.

A

Admiral Tool & Die Co., Inc., 45-10 Vernon Blvd., Long Island City 1, N. Y. 278
Aetna Scientific Co., Second and Spring Sts., Everett 49, Mass. 668
Alberene Stone Corp. of Virginia, 419 Fourth Ave., New York 16, N. Y. 79
Allegheny Ludlum Steel Corp., 2020 Oliver Bldg., Pittsburgh 22, Pa. 250-252-254
Allis-Chalmers Manufacturing Co., Milwaukee 1, Wis. 48-49
Allis Co., The Louis, Milwaukee 7, Wis. ..320-322
Alloy Steel Products Co., Linden, N. J. ..646-647
Aloe Scientific Division of the A. S. Aloe Co., 19th and Olive Sts., St. Louis, Mo. .665-666
Alsop Engineering Corp., Milldale, Conn. ... 293
Aluminum Co. of America, Pittsburgh 19, Pa. 70-71
American Air Filter Co., Inc., 1st and Central Aves, Louisville 8, Ky. 413-414
American Balance Corp., 48 Potter Ave., New Rochelle, N. Y. 248
American Bridge Co., Frick Bldg., Pittsburgh, Pa. 76-77
American Chemical Society, 1155 Sixteenth St., N.W. Washington 6, D. C. 7E-26-27
American Chemical Society News Service, 60 E. 42nd St., New York 17, N. Y. ..7E-26-27
American Hard Rubber Co., 93 Worth St., New York 13, N. Y. 303-305
American Instrument Co., Inc., 8030-8050 Georgia Ave., Silver Spring, Md. 385-387
American Machine and Metals, Inc., Tolhurst Centrifugals Division, East Moline, Ill. 68-69
American Monomer Corp., 511 Lancaster St., Leominster, Mass. 35-36
American Optical Co., Instrument Division, Buffalo 15, N. Y. 461A
American Platinum Works, The, 231 New Jersey R. R. Ave., Newark 5, N. J. ..458-459
American Polymer Corp., 101 Foster St., Peabody, Mass. 35-36
American Resinous Chemicals Corp., 103 Foster St., Peabody, Mass. 35-36
American Sterilizer Co., Erie, Pa. 820
American Tool & Machine Co., The, 30 Church St., New York 7, N. Y. 412
American Wheelabrator & Equipment Corp., Mishawaka, Ind. .....481 to 484
Amersil Co., Inc., 1471 Chestnut Ave., Hillside, N. J. 453-454
Ampco Metal, Inc., 1745 S. 38th, Milwaukee 46, Wis. 268
Analytical Chemistry, 330 W. 42nd St., New York 18, N. Y. 7E-26-27
Andrews-Knapp Construction Co., Inc., 23-15 Borden Ave., Long Island City 1, N. Y. 23
Angel & Co., Inc., H. Reeve, 52 Duane St., New York 7, N. Y. 214
Ansul Chemical Co., Marinette, Wis. 81-82
Arrow-Hart & Hegeman Electric Co., The, 103 Hawthorn St., Hartford 6, Conn. .. 810
Artisan Metal Products, Inc., Boston, Mass., 540-541-542
Associated Cooperage Industries of America, Inc., The, 408 Olive St., St. Louis 2, Mo. . 242
Atlas Powder Co., Wilmington 99, Del. ...46-47
Austenal Laboratories, Inc., Microcast Division, 224 E. 39th St., New York 16, N. Y. 573A

Booth No.

Autoclave Engineers, Inc., 860 E. 19th St., Erie, Pa. 612

B

Bailey Meter Co., 1050 Ivanhoe Road, Cleveland 10, Ohio 56
Baird Associates, Inc., 33 University Road, Cambridge 38, Mass. 670
Baker & Co., Inc., 113 Astor St., Newark 5, N. J. 451-452
Baker Perkins, Inc., Saginaw, Mich. 62-63
Barco Manufacturing Co., 1801 to 1815 Winnemac Ave., Chicago 40, Ill. 518
Barco Oil Co., Wax Division, P. O. Box 2009, Tulsa, Okla. 629-630
Barnstead Still and Sterilizer Co., 2 Lanesville Terrace, Forest Hills, Boston 31, Mass. 229-231
Barrett-Cravens Co., 4613 S. Western Blvd., Chicago 9, Ill. 239-241
Bartlett & Snow Co., The C. O., 6200 Harvard Ave., Cleveland 5, Ohio 427-428
Bean Division, John, Food Machinery and Chemical Corp., P. O. Box 840, Lansing 4, Mich. 429
Beckman Instruments, Inc., South Pasadena, Calif. 265-267-269
Belco Industrial Equipment Division, Inc., 52 Iowa Ave., Paterson 3, N. J. 574
Belgian Electric Sales Corp., 1 E. 53rd St., New York 22, N. Y. 824
Bemis Bro. Bag Co., 408 Pine St., St. Louis 2, Mo. 338-340
Berger Manufacturing Division, Republic Steel Corp., Canton, Ohio 434-435-436
Bersworth Chemical Co., Framingham, Mass. 803
Bird Machine Co., South Walpole, Mass., 535-536-543-544
Black, Sivalls & Bryson, Inc., 7500 E. Twelfth St., Kansas City 3, Mo. 496-497
Blaw-Knox Co., Pittsburgh, Pa. 13-14
Blickman, Inc., S., Weehawken, N. J. ..474-475
Bogue Electric Mfg. Co., 52 Iowa Ave., Paterson 3, N. J. 574
Boler Petroleum Co., 121 S. Broad St., Philadelphia 7, Pa. 629-630
Bolt and Nut Division, Republic Steel Corp., Cleveland, Ohio 434-435-436
Bowen Engineering, Inc., North Branch, N. J. 400-400A-461B
Bowser, Inc., 1302 E. Creighton Ave., Fort Wayne 2, Ind. 573
Brabender Corp., Rochelle Park, N. J. 289
Bramley Machinery Corp., Edgewater, N. J. 524-525
Branson Instruments, Inc., 436 Fairfield Ave., Stamford, Conn. 659A
Brinkman & Co., C. A., P. O. Box 532, Great Neck, N. Y. 467
British American Carbon Corp., 18 E. 48th St., New York 17, N. Y. 734
Brooks Rotometer Co., Lansdale, Pa. 449-450
Brush Development Co., The, 3405 Perkins Ave., Cleveland 14, Ohio 662A
Buffalo Apparatus Corp., Buffalo, N. Y. .226-228
Buffalo Meter Co., 2917 Main St., Buffalo 14, N. Y. 728
Buflovak Equipment, Division of Blaw-Knox Co., Buffalo 11, N. Y. 6
Builders-Providence, Inc., 345 Harris Ave., P. O. Box 1342, Providence 1, R. I., 493-494-495

Booth No.

Burling Instrument Co., 5 Bose Ave., South Orange, N. J. 409

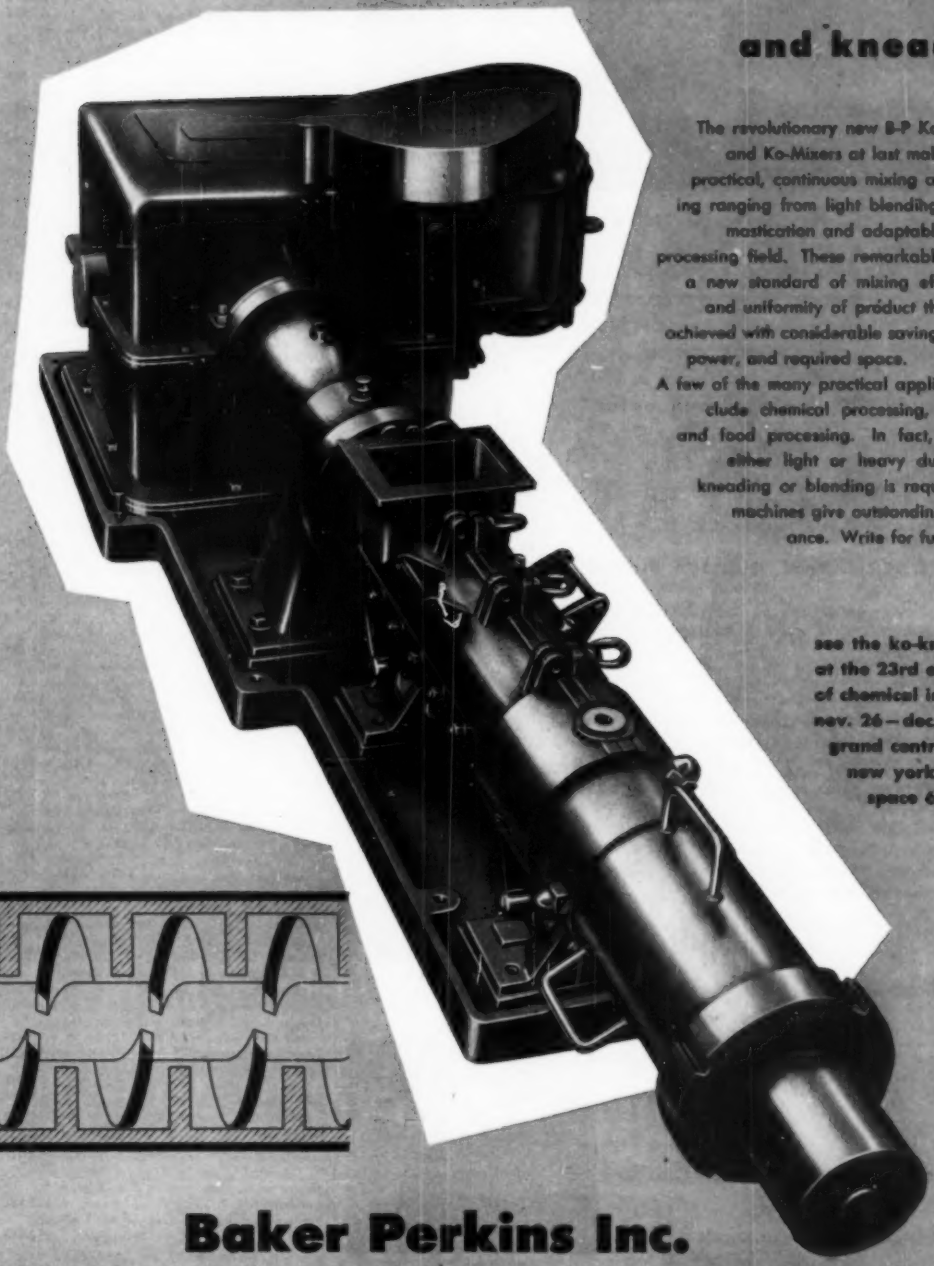
C

Cambridge Instrument Co., Inc., Grand Central Terminal, New York 17, N. Y. ..330-332
Cameron Iron Works, Inc., P. O. Box 1212, Houston 1, Texas 661
Carbide and Carbon Chemicals Co., Division of Union Carbide and Carbon Corp., 30 E. 42nd St., New York 17, N. Y. 17
Carpenter Steel Co., The Alloy Tube Division, Union, N. J. 500-501
Carver, Inc., Fred S., 1 Chatham Road, Summit, N. J. 237
Central Scientific Co., 1700 Irving Park Road, Chicago 13, Ill. 491-492
Centrico, Inc., 233 Broadway, New York 7, N. Y. 813
Chamberlain Engineering Corp., Akron, Ohio, ...89-90-91
Chase Equipment Corp., 47 E. 19th St., New York 3, N. Y. 547-548
Chemical Abstracts, 330 W. 42nd St., New York 18, N. Y. 7E-26-27
Chemical Engineering, 330 W. 42nd St., New York 18, N. Y. 42
Chemical Engineering Catalog, 330 W. 42nd St., New York 18, N. Y. 26-27
Chemical and Engineering News, 330 W. 42nd St., New York 18, N. Y. 7E-26-27
Chemical Engineering Progress, 120 E. 41st St., New York 17, N. Y. 471
Chemical Materials Catalog, 330 W. 42nd St., New York 18, N. Y. 26-27
Chemical Processing, 111 E. Delaware Place, Chicago 11, Ill. 506
Chemical Pump and Equipment Corp., 75 West St., New York 6, N. Y. 431A
Chemical Week, 330 W. 42nd St., New York 18, N. Y. .....42 & 2BE & 2BW
Chemicalloid Laboratories, Inc., 30 Church St., New York 7, N. Y. 257
Chikson Co., Brea, Calif. 678-679
Cleaver-Brooks Co., Milwaukee 12, Wis. .709-710
Cleveland Worm & Gear Co., The, 3249-59 E. 80th St., Cleveland 4, Ohio 502-503
Coleman Instruments, Inc., 318 Madison St., Maywood, Ill. .....3B1 & A (Mezz)
Colton Co., Arthur—Division of Snyder Tool & Engineering Co., 3400 E. Lafayette Ave., Detroit 7, Mich. 613-614
Combustion Engineering—Superheater, Inc., 200 Madison Ave., New York 16, N. Y. .. 266
Combustion Engineering—Superheater, Inc., Raymond Pulverizer Division, 1315 N. Branch Ave., Chicago 22, Ill. 67
Commercial Filters Corp., 18 W. Third St., Boston 27, Mass. 499
Commercial Solvents Corp., 745 Fifth Ave., New York 22, N. Y. 55
Conkey Filter Unit, General American Transportation Corp., 10 E. 49th St., New York 17, N. Y. 285-287
Conneaut Rubber and Plastics Corp., Conneaut, Ohio 89-90-91
Consolidated Engineering Corp., 620 N. Lake Ave., Pasadena 4, Calif. 703-704
Container Co., The, Division Continental Can Co., Inc., 100 E. 42nd St., New York 17, N. Y. 243-245

(Continued on page 38)

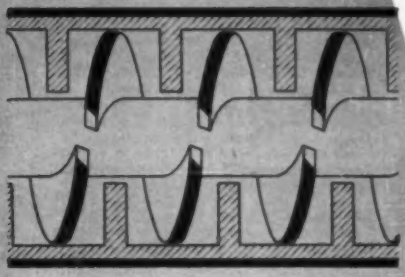
Booth numbers 2 to 94, first floor; 201 to 395, second floor; 400 to 575, third floor and 601 to 834, fourth floor.

announcing! the new Baker Perkins "list system" ko-kneaders for continuous mixing and kneading



The revolutionary new B-P Ko-Kneaders and Ko-Mixers at last make possible practical, continuous mixing and kneading ranging from light blending to heavy mastication and adaptable to every processing field. These remarkable units set a new standard of mixing effectiveness and uniformity of product that can be achieved with considerable savings in labor, power, and required space.

A few of the many practical applications include chemical processing, foundries, and food processing. In fact, whenever either light or heavy duty mixing, kneading or blending is required these machines give outstanding performance. Write for further facts.

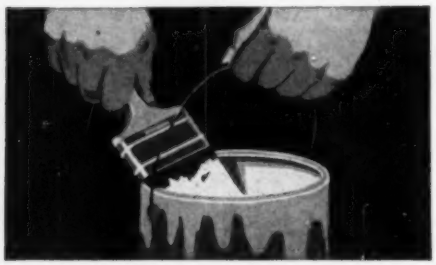


see the ko-kneader at the 23rd exposition of chemical industries nov. 26—dec. 3, grand central palace, new york city space 62-63

Baker Perkins Inc.

Chemical Machinery Division, Saginaw, Michigan

from paint



to potato chips!

wide-awake process men value

DOWTHERM

the **MODERN** heat transfer medium

Yes, in addition to its economy and efficiency, DOWTHERM® is safer!

DOWTHERM is used in an indirect system in which the fire is removed from any flammable material in process. High-temperature operations can now be accurately and safely controlled. DOWTHERM presents little hazard in handling, in shipping and storage.

Today DOWTHERM users, whether they be paint manufacturers or food processors—or engaged in any other high-temperature operation—enjoy a security unknown in earlier systems. If your operations require precise heating in the 300°-750° F. range, write to Dow for complete information about DOWTHERM.

THE DOW CHEMICAL COMPANY
MIDLAND, MICHIGAN

THE DOW CHEMICAL COMPANY
DEPT. DO-25
MIDLAND, MICH.

Name_____ Title_____

Company_____

Address_____

City_____ State_____

DOW
CHEMICALS
INDISPENSABLE TO INDUSTRY AND AGRICULTURE

LIST OF EXHIBITORS

(*Continued from page 36*)

Booth No.

Continental-Diamond Fibre Co., *Marshallton, Del.* 51
Cooper Alloy Foundry Co., The, *Hillside 5, N. J.* 563-566
Corning Glass Works, *Corning, N. Y.*, 391-393-395
Cowles Co., The, *Cayuga, N. Y.* 572
Crane Co., *836 S. Michigan Ave., Chicago 5, Ill.* 297
Croll-Reynolds Co., Inc., *751 Central Ave., Westfield, N. J.* 505
Crucible Steel Co. of America, *405 Lexington Ave., New York 17, N. Y.* 635
Culvert Division, Republic Steel Corp., *Cleveland, Ohio* 434-435-436
Cyclone Fence Division, American Steel & Wire Co., *Waukegan, Ill.* 76-77

D

Darco Department, Atlas Powder Co., *60 E. 42nd St., New York 17, N. Y.*..... 46-47
Day Co., The, *810 Third Ave. N.W., Minneapolis 13, Minn.* 439
Day Co., Inc., The J. H., *Cincinnati 22, Ohio* ..... 718 to 721
DeLaval Separator Co., The, *Poughkeepsie, N. Y.* 323
DeZurik Shower Co., *Sartell, Minn.*..... 727
Dicalite Division, Great Lakes Carbon Corp., *612 S. Flower St., Los Angeles 14, Calif.*.. 86
Dorr Co., The, *Barry Pl., Stamford, Conn.*.. 64
Dracco Corp., *Harvard Ave. and E. 116th St., Cleveland 5, Ohio* 662
Duriron Co., Inc., The, *Box 1019, Dayton 1, Ohio* 19-20

E

Eagle-Picher Sales Co., The, *900 American Bldg., Cincinnati 1, Ohio* 672-673
Eastern Industries Incorporated, *296 Elm St., P. O. Box 1575, New Haven 6, Conn.* 220-222-224
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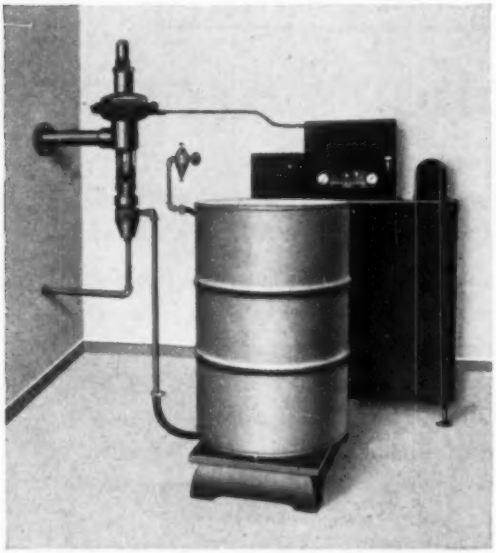
FEED PROCESS CHEMICALS

Continuously-
Automatically-
Accurately-

BY WEIGHT !

%Proportioneers, Inc.% new Weight-O-Matic Scale offers the process industries a simplified yet accurate method for feeding chemicals by weight in continuous process applications — either at constant rates or in response to process variables. Rates of feed are infinitely adjustable, from a few ounces to many pounds per minute. The chemicals may be injected into vacuum or pressure without affecting performance. This new scale comes in a wide range of capacities and uses the %Proportioneers% Loss-in-Weight principle. It may be equipped for automatic rebalancing and reloading and two Weight-O-Matics may be used in parallel for uninterrupted feeding.



%Proportioneers% Weight-O-Matic drum size automatic scale for loads up to 1,000 lbs. gross.

The Weight-O-Matic is ideally adapted for use in the laboratory or full scale plant production. Units can be supplied for feeding gases, liquids, or slurries. The scale tank can be pressurized or an eductor or gravity feed can be employed for discharging into flowing streams. Because the Weight-O-Matic responds only to weight demand, no correction factors for temperature changes need be applied. Volumetric calibration is also unnecessary. The feed is smooth, continuous, and without pulsation.

The Weight-O-Matic may be equipped with totalizers, recorders, and other accessories. The basic unit contains an alarm circuit which may be connected to a visible or audible alarm system to warn the operator of over- or under-feeding and inform him when the chemical reaches minimum and recharging is required.

Ask for Bulletins
and Recommendations

% PROPORTIONEERS, INC. %

Write to %PROPORTIONEERS, INC.%, 419 Harris Ave., Providence 1, R. I.

Technical service representatives in principal cities of the United States, Canada, Mexico and other foreign countries.

The Philosopher's Stone

In the Middle Ages the alchemists sought to make—with the aid of Sulphur—a wondrous thing called the "philosopher's stone". With this "stone", they planned to work miracles of many kinds. They hoped, by touching it to base metals, to convert those metals into precious gold.

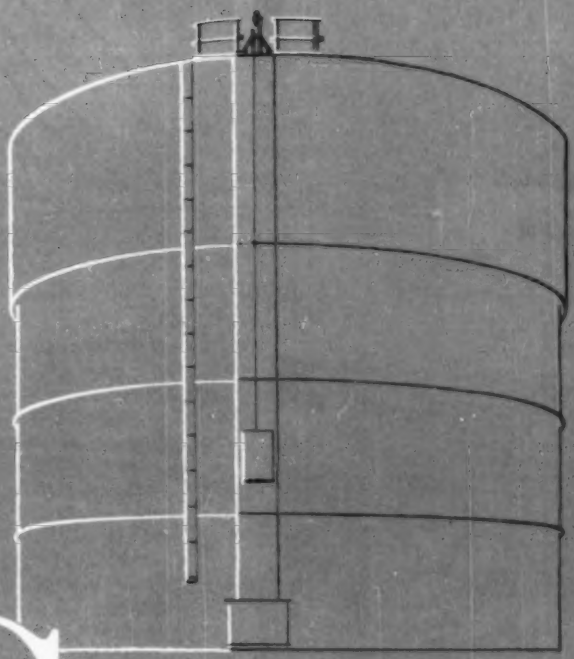
Although the alchemists' dreams for Sulphur were never realized, Sulphur adds to mankind's natural wealth through its role in fertilizer. It enhances the earth's riches by helping to convert air and soil constituents into growing plants. Sulphur is used not only in the form of sulphuric acid for the manufacture of most fertilizers but also as an ingredient in many of them to correct soil deficiencies. Thus, through increased yield from our agricultural lands, Sulphur makes another basic contribution to supplying the world's necessities.

FREEPORT SULPHUR COMPANY, *oldest United States producer of crude sulphur, has been supplying this essential raw material for over 35 years.*

FREEPORT SULPHUR COMPANY

OFFICES: 122 East 42nd Street, New York 17, N. Y. • MINES: Port Sulphur, Louisiana • Freeport, Texas

Wiggins ... THE ONLY MODERN TROUBLE-FREE GASHOLDER



There is only one

MODERN

Gasholder

...that's the Wiggins—proved by 15 years of service

Many up to date plants, with last-minute equipment and an efficient operating organization, still use old-fashioned gasholders that require constant attention and present continuous hazards.

The WIGGINS modern gasholder cures all that. Actual operation for over 15 years proves that the WIGGINS functions with equal efficiency, come high water—hurricane or earthquake—winter or summer—any climate, anywhere.

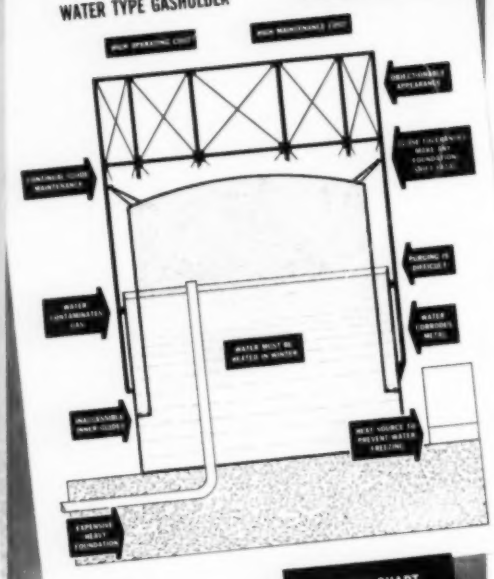
The WIGGINS holds gas from foundation to roof—there's very little unused space. It can't blow out, leak, stretch or jam—and extreme temperatures make no difference in its operation. The WIGGINS is the simplest, safest, surest and most fool-proof gas-holding device yet developed.

FOR MORE INFORMATION ON THE ONLY MODERN GASHOLDER, SEE NEXT PAGE

THE WIGGINS SOLVES THE PROBLEMS CREATED BY OLD-FASHIONED GAS-HOLDING DEVICES...

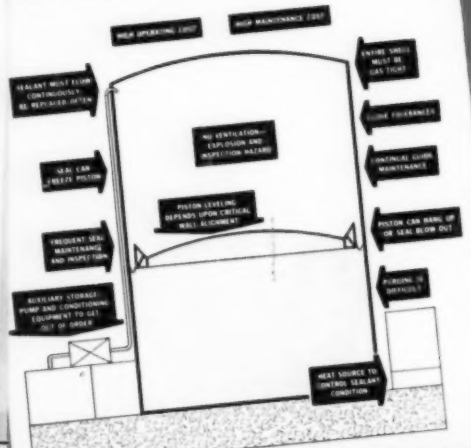
HAZARD CHART

WATER TYPE GASHOLDER



HAZARD CHART

PISTON TYPE WITH FLUID SEAL


HIGH OPERATING COST
HIGH MAINTENANCE COST
SEALANT MUST FLOW CONTINUOUSLY TO REPLENISH OFTEN
ENTIRE SHELL MUST BE GAS TIGHT
CLOSE TOLERANCES
NO VENTILATION—EXPLOSION AND INSPECTION HAZARD
SEAL CAN FREEZE PISTON
CONTINUAL FLOOR MAINTENANCE
PISTON LEVELING DEPENDS UPON CRITICAL WALL ALIGNMENT
PISTON CAN WARP OR SEAL BLOW OUT
FREQUENT SEAL MAINTENANCE AND INSPECTION
PURGING IS DIFFICULT
AUXILIARY STORAGE PUMP AND CONDITIONING EQUIPMENT TO GET OUT OF ORDER
HEAT SOURCE TO CONTROL SEALANT CONDITION

Wiggins

THE ONLY MODERN GASHOLDER

The heart of the WIGGINS gasholder is a chemically inert, virtually indestructible fabric. Tested for more than 15 years in actual use, it has shown no sign of deterioration or leakage. Installed in the gasholder, it is not exposed to friction or wear.

The WIGGINS is simple; no intricate moving parts—no guide rollers to get out of line, no close tolerances to jam up with ice or frost, no tracks to get out of alignment with settling foundations, and no sealant to require accessory equipment. Filling this gasholder is as easy and as direct as blowing up a paper sack—yet it is safer and surer than any other gasholder. Only the lower portion of the steel structure needs to be gas-tight—and the rest can be thoroughly ventilated. Inexpensive piers with a concrete ring wall make a secure foundation.

No wonder that the city of New York, for its new sewage-disposal system, chose WIGGINS; or that many chemical plants, tired of contaminated gas and constant care are adding WIGGINS gasholders or converting old-fashioned hazardous types to the WIGGINS with the virtually indestructible fabric heart. For full information, be sure to send the coupon.

1 NO OPERATING COSTS | 2 REDUCED MAINTENANCE COSTS | 3 QUICK PURGING

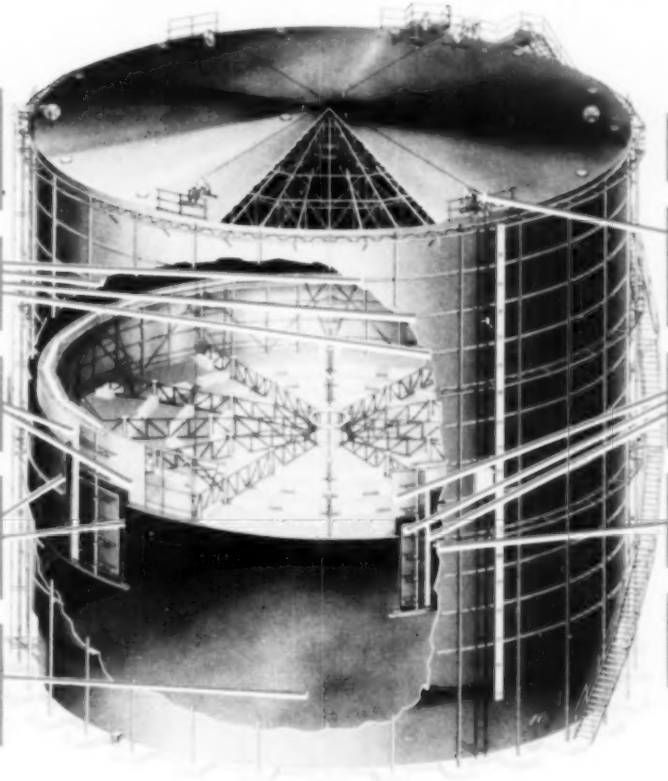
EMPTY, showing top of piston and corrugated fender. Note weights on top of piston to regulate pressure.

Wiggins

THE ONLY MODERN TROUBLE-FREE GASHOLDER

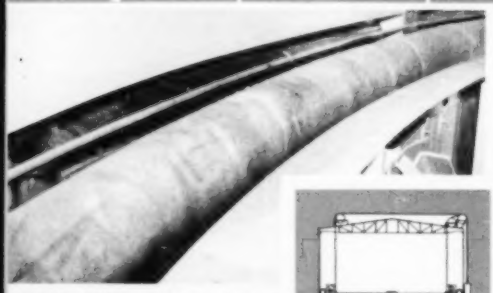
. . . *easier* to erect . . . costs virtually *nothing* to maintain . . . .

. . . gives *trouble-free* performance indefinitely

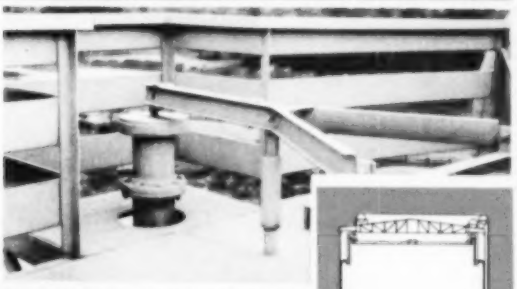


- PISTON RISES NEARLY TO TOP—MINIMUM OF WASTE SPACE
- TOP SECTION OF SHELL COMPLETELY VENTILATED
- WIDE CLEARANCES SIMPLIFY OPERATION
- GASTIGHT FRICTIONLESS SEAL NOT AFFECTED BY WEATHER
- PISTON RESTS ON BOTTOM—LESS THAN ½ OF 1% FOR PURGING
- CAN BE BUILT ANY SIZE
- LEVELING DEVICE—INDEPENDENT OF SIDE WALL—KEEPS PISTON LEVEL
- FENDERS PREVENT ALL TENSION IN SEAL
- SHELL IS GASTIGHT UP TO SEAL CONNECTION
- NO CONTAMINATION OF GAS

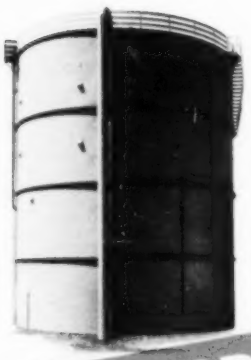
1 FREEDOM FROM WEATHER HAZARDS | 5 CLEAN UNCONTAMINATED GAS | 6 CLOSE CONTROL OF GAS PRESSURE | 7 REDUCED ATMOSPHERIC CORROSION | 8 LOW COST FOUNDATIONS



HALF FULL position, showing inflated seal constructed of Neoprene coated asbestos fabric.

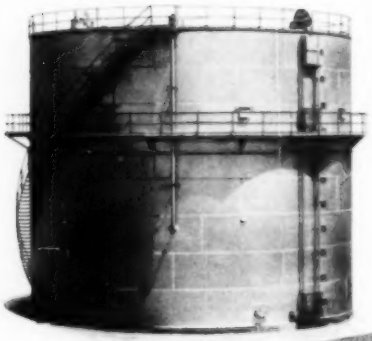


FULL position, view of mechanically operated relief valve. Releases gas if tank capacity is exceeded.



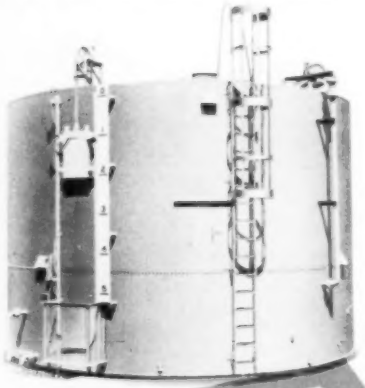
IN NEW YORK

New York City's newest and largest sewage disposal plant, at Owls Head, stores digestor gas in this 100,000 cu. ft. Wiggins holder.



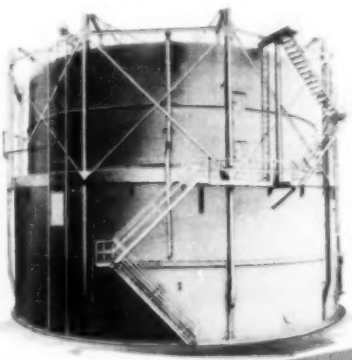
IN LOS ANGELES

This 100,000 cu. ft. Wiggins gasholder stores digestor gas in the new $41,000,000 Hyperion Activated Sludge sewage disposal plant at Los Angeles.



IN CANADA

Canadian Liquid Air Company stores oxygen in this Wiggins holder—eliminating low temperature problems as well as ice and snow load difficulties.



IN NEW JERSEY

Pure Carbonic Company effects tremendous savings through conversion of this CO_2 holder from troublesome, expensive wet seal to trouble-free Wiggins.

General American Transportation Corp., 135 So. LaSalle St., Chicago 90, Ill.

Gentlemen:

☐ Please send me full information about the Wiggins Gasholder.
☐ Please have a representative get in touch with me.

I am interested in storing _____

Name _____

Firm _____ Position _____

Address _____

City _____ Zone _____ State _____

Wiggins

THE ONLY MODERN GASHOLDER

GENERAL AMERICAN

GENERAL AMERICAN TRANSPORTATION CORPORATION

General Sales Office

135 South LaSalle Street, Chicago 90, Illinois

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Parker Appliance Corp., The, 17325 Euclid Ave., Cleveland 12, Ohio 21
Patterson Foundry & Machine Co., The, East Liverpool, Ohio 715-716-717
Patterson Kelley Co., Inc., The, East Stroudsburg, Pa. 274-276
PerfeKtum Products Co., 300 Fourth Ave., New York 10, N. Y. 370
Perkin-Elmer Corp., The, Glenbrook, Conn. 531-532
Perl Machine Manufacturing Co., 68 Jay St., Brooklyn 1, N. Y. 644-645
Perlite Division, Great Lakes Carbon Corp., 18 E. 48th St., New York 17, N. Y. 734
Permutit Co., The, 330 W. 42nd St., New York 18, N. Y. 537-538
Pfaudler Co., The, 1000 West Ave., Rochester 3, N. Y. 72-73
Pfizer & Co., Inc., Chas., 630 Flushing Ave., Brooklyn 6, N. Y. 5
Philadelphia Gear Works, Inc., G St. below Erie Ave., Philadelphia 34, Pa. 78

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Photovolt Corp., 95 Madison Ave., New York 16, N. Y. 270-272
Pioneer Division, Scott & Williams, Inc., 350 Fifth Ave., New York 1, N. Y. 801
Pittsburgh Corning Corporation, 307 Fourth Ave., Pittsburgh 22, Pa. 643
Pittsburgh Equitable Meter Division, Rockwell Manufacturing Co., 400 N. Lexington Ave., Pittsburgh 8, Pa. 61
Platecoil Division of Kold-Hold Manufacturing Co., Lansing 4, Mich. 707-708
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Pneumatic Scale Corp., Ltd., Quincy 71, Mass. 22
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Precision Scientific Co., 3737 W. Courtland St., Chicago 47, Ill. 701-702
Premier Mill Corp., 218 Genesee St., Geneva, N. Y. 312-314
Pressed Steel Tank Co., West Allis Sta., Milwaukee 14, Wis. 348-350-352
Proctor & Schwartz, Inc., 7th St. and Tabor Road, Philadelphia 20, Pa. 15
Productive Equipment Corp., 2926 W. Lake St., Chicago 12, Ill. 549
Progressive Architecture, 330 W. 42nd St., New York 18, N. Y. 26-27
%Proportioneers, Inc.%, P. O. Box 1442, Providence 1, R. I. 477-478
Pulva Corp., 550 High St., Perth Amboy, N. J. 568
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Putman Publishing Co., 111 E. Delaware Place, Chicago 11, Ill. 506

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Republic Steel Corp., 3100 E. 45th St., Cleveland 4, Ohio 434-435-436
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Rietz Manufacturing Co., 150 Todd Road, Santa Rosa, Calif. 648
Robbins & Myers, Inc., Springfield 99, Ohio 639-640
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Rockwell Manufacturing Co., Nordstrom Valve Division, Pittsburgh Equitable Meter Division, 400 N. Lexington Ave., Pittsburgh 8, Pa. 61
Rosevear Co., M. B., 2 Broad St., Bloomfield, N. J. 602
Ross & Son Co., Charles, 148-156 Classon Ave., Brooklyn 5, N. Y. 407

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Ruggles-Coles Engineering Co., 240 Arch St., York, Pa. 60

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Sadtler & Son, Inc., Samuel P., 2100 Arch St., Philadelphia 3, Pa. 829
Safety Car Heating and Lighting Company, Inc., The—Entoleter Division, P. O. Box 904, New Haven 4, Conn. 460-461
Saran Lined Pipe Co., 2415 Burdette Ave., Ferndale, Mich. 621
Sarco Co., Inc., Empire State Bldg., New York 1, N. Y. 11
Schaub Engineering Co., Fred H.—Magnetrol, Inc., Division, 2110 S. Marshall Blvd., Chicago 23, Ill. 729
Schmieg Industries, Inc., 1 Hunter St., Long Island City, N. Y. 808
Schneible Co., Claude B., P. O. Box 502, Roosevelt Annex, Detroit 32, Mich. 421-422
Scientific Development Co., Box 795, State College, Pa. 812
Scientific Glass Apparatus Co., Inc., 100 Lakewood Terrace, Bloomfield, N. J., 215-217-219
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Simplicity Engineering Co., Durand, Mich. 706
Sjostrom Co., John E., 1715 N. Tenth St., Philadelphia 22, Pa. 664
Sly Manufacturing Co., Inc., The W. W., 4700 Train Ave., Cleveland 2, Ohio 487-488
Snell, Inc., Foster D., 29 W. 15th St., New York 11, N. Y. 37
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Sparkler Manufacturing Co., Mundelein, Ill. 516-517
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Standard Steel Corp., 5001 Boyle Ave., Los Angeles 58, Calif. 575
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Tennessee Eastman Co., Division of Eastman Kodak Co., S. Kingsport, Tenn. 725-726

(Continued on page 48)

NOTES FROM THE PUMP ENGINEER'S HANDBOOK

Little Details Like the XXX Seal Make Johnston Pumps Better!

Johnston pump bowl assemblies fitted with enclosed impellers have the Johnston XXX Seal – just another small detail that makes each Johnston the pump with real inside qualities. The design of the Johnston Seal, formed by the impeller shroud and the wear ring, provides sealing surfaces which prevent *any loss of efficiency* caused by liquid by-passing.

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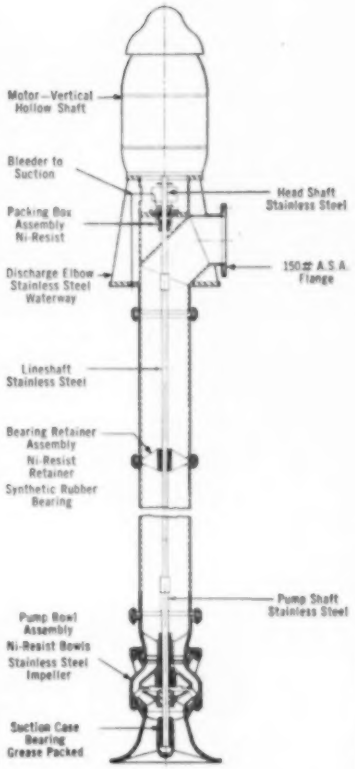

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Johnston Pump Company is a pioneer in the application of the vertical pump for the handling of acids and highly corrosive solutions. With complete information about the fluid to be pumped and the service requirements, our Engineering Department will gladly submit typical design drawings and specifications.

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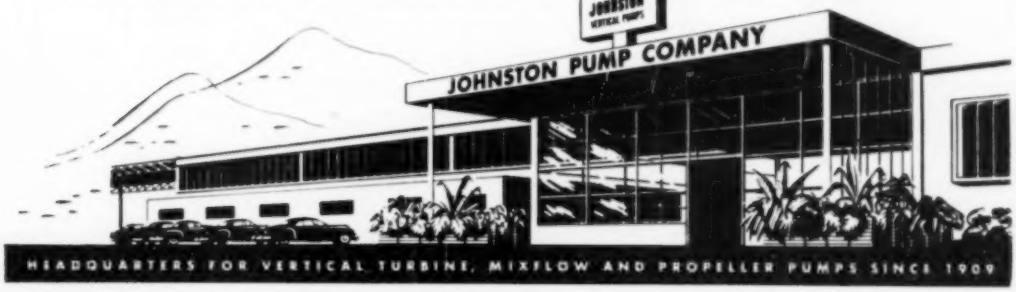

HEADQUARTERS FOR VERTICAL TURBINE, MIXFLOW AND PROPELLER PUMPS SINCE 1909

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Toledo Scale Co., Toledo 12, Ohio 448
Tolhurst Centrifugal Division, American Machine and Metals, Inc., East Moline, Ill. 68-69
Trent, Inc., 201-299 Leverington Ave., Philadelphia 27, Pa. 526-527
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Tri-Homo Corp., Salem, Mass. 625-626
Tripard Manufacturing Co., Inc., 38 Murray St., New York 7, N. Y. 411
Troy Engine and Machine Co., 1492 Railroad Ave., Troy, Pa. 667
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United States Steel Export Co., 30 Church St., New York 7, N. Y. 76-77
United States Steel Products Co., 28 Rockefeller Plaza, New York 20, N. Y. 76-77
United States Steel Supply Co., 1301 Wabansia Ave., Chicago 90, Ill. 76-77
United States Stoneware Co., The, 60 E. 42nd St., New York 17, N. Y. 89-90-91

V

Van Nostrand Co., D., Inc., 250 Fourth Ave., New York 3, N. Y. 85
Vanton Pump Corp., Empire State Bldg., New York 1, N. Y. 705
Victor Chemical Works, 141 W. Jackson Blvd., Chicago 4, Ill. 619-620
Vogt Machine Co., Henry, 10th & Ormsby Sts., Louisville, Ky. 725-726

W

Walker-Wallace, Inc., 137 Arthur St., Buffalo 7, N. Y. 818
Wallace & Tiernan Co., Inc., Newark 1, N. J. 519-520-521
Walworth Co., 60 E. 42nd St., New York 17, N. Y. 316-318
Watson-Stillman Co., Aldena Road, Roselle, N. J. 814
Welch Manufacturing Co., W. M., 1515 Sedgwick St., Chicago 10, Ill. 405-406
Westinghouse Electric Corp., 511 Wood St., P. O. Box 868, Pittsburgh 30, Pa. 832-833-834
Weston Electrical Instrument Corp., Newark 5, N. J. 263
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Wiggins Gasholder Division, General American Transportation Corp., 135 S. LaSalle St., Chicago 90, Ill. 285-287
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York Co., Inc., Otto H., 69 Glenwood Place, East Orange, N. J. 380

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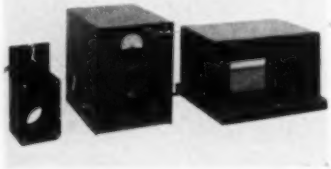
2 • ALLOY VALVES. Demonstration of the manufacture of alloy valves from the making of a pattern and mold through machining and finishing. Also a full line of high alloy corrosion resistant valves of various types, sizes, and materials. Alloy Steel Products Co., Booth 646.

(Continued on page 50)



Electronic unit of R. C. A. for detecting tramp metal in foods and chemicals.

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AT 158 TO 284 DEG. F.

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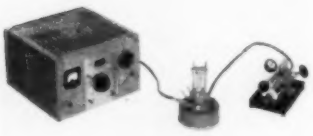
DATA SERVICE

(*Continued from page 48*)

3 • ***LABORATORY FURNITURE AND EQUIPMENT.*** Moduline sectionalized steel furniture with stainless steel and alberene stone tops plus analytical apparatus, micro-burettes, scintillation counters, micro-electrophoresis equipment, etc. Aloe Scientific Co., Booth 665.

4 • ***MIXERS AND FILTERS.*** An all-way adjustable swivel mixer mounting bracket for stainless steel tanks. Has quick adjustment to any desired position for blending, dissolving and mixing. Also sealed-disc filter in operation with a transparent housing for observation. Alsop Engineering Corp., Booth 293.



Equipment of the Brush Development Co. for developing ultrasonic energy.

5 • ***CENTRIFUGALS.*** For the chemical process industries, a display of processing centrifugals; a 26″ center-slung centrifugal with a stainless steel basket; a 40″ with rubber lined case; 48″ and a 12″ laboratory stainless steel basket and case unit with an infinite variable speed and hydraulic drive. American Machine & Metals, Inc., Booth 68.

6 • ***EMULSIONS, FILMS, COLLOIDS.*** Many new products covering high styrene, butadiene-latex for film forming purposes, synthetic acrylic thickeners and protective colloids, styrene copoylmer emulsions for water paints, etc., acrylic resins, acrylic butadiene copolymers, etc. American Polymer Corp., Booth 35.

7 • ***ADHESIVES, HEAT SEALS, AND EMULSIONS.*** Various types of adhesives for bonding leather, paper, rubber, plastics to paper, and compounds for industrial adhesives, tile cements, etc. Heat seals for use with synthetic rubbers, for high-melting paraffin waxes in manufacture of heat seal paper coatings; tackifiers for natural rubber latex, for compounding industrial adhesives imparting increased cohesion, high bond strength and dry tack. Heat seals for Barrier wrap materials, coatings for nylons to meet military specifications for ponchos, etc. American Resinous Chemicals Corp., Booth 35.

8 • ***CORROSION-RESISTANT METAL.*** Ampco metal (aluminum bronze) and equipment for the chemical process industry. Will include plug cocks and valves, centrifugal pumps, pipe, exchanger tubes, fittings, castings, welding rod and safety tools as well as other fabrications. Ampco sheet and plate now approved in boiler code. Ampco Metal, Inc., Booth 268.

9 • ***FILTER PAPER.*** Display of filter papers for chromatography and other filter papers for filter presses and filtering machines. H. Reeve Angel & Co., Booth 214.

10 • ***SAFETY STARTERS.*** Right-angle magnetic starters and contactors in explo-safe enclosures for motors and contactors where explosive gases, dust, materials exist. Approved by Underwriters' Laboratories. The Arrow-Hart & Hegeman Electric Co., Booth 810.

10A • ***KNEADERS.*** For continuous mixing and kneading a showing of Ko-Kneaders which give product uniformity and power and time savings. For light blending to heavy and intense mixing. Also centrifuges and laboratory mixers. Baker Perkins, Inc., Booth 62.

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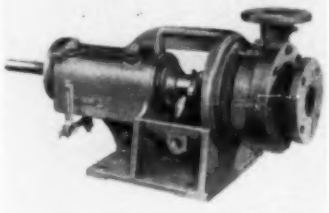

Chemical pump pedestal mounted, for handling corrosives. Allis-Chalmers.

12 • ***WATER TREATMENT.*** A demonstration of stills and demineralizers. Includes water purification equipment for all applications—industrial, laboratory, hospital, pharmaceutical. A bantam demineralizer with a direct reading purity meter plus demonstration of quick purity test for water. Barnstead Still & Sterilizer Co., Booth 229.

14 • ***HIGH PRESSURE PUMPS.*** High pressure pumps for the chemical process industry, plunger type, outside packed, horizontal enclosed triplex power with fluid end in various alloys. Capacities from 0.5 to 80 gals./min. and pressures proportionately reduced in relation to capacity from 100 to 6000 lbs./sq.in. John Bean Division, Food Machinery & Chemical Corp., Booth 429.

15 • ***FILTERS.*** A full size Bird high speed continuous filter with a lucite case so that construction and operation may be observed. Operates above 3000 rev./min. with high capacity and tonnage of filtered solids per hour. Also a Bird-Young universal vacuum filter for separation of slow filtering and free filtering solids from liquid. Panelled cylinder permits multi-stage countercurrent washing. Filter cake removed by pneumatic "blow-back." Bird Machine Co., Booth 535.

16 • ***CONTROL AND SAFETY EQUIPMENT.*** Various control units, liquid level, diaphragm valve, angle valve, etc., and a full display of various safety head equipment, bolted union, combination safety, rupture discs, vacuum supports, etc. Also, a pressure-vacuum vent valve with flame arrestor unit for the petroleum industry. Well-illustrated catalog available on safety heads detailing capacities, amount of gas vented at specific pressures, etc. Black, Sivalls & Bryson, Inc., Booth 496.

17 • ***SPRAY DRYERS.*** On display a laboratory spray dryer, a model of full size industrial units. Bowen will show nozzle atomization in addition to centrifugal atomization. Also a high speed spray machine, a high speed non-fouling evaporator, and a dust collector. Bowen Engineering, Inc., Booth 400-461B.

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(*Continued on page 53*)

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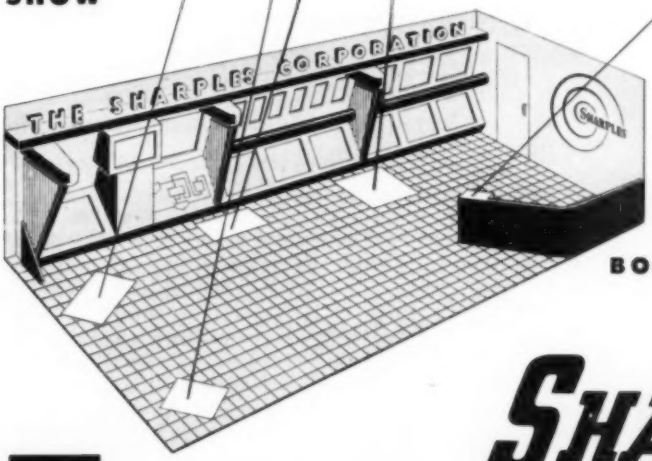

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- ☐ B-102 Top Entering Mixers (Turbine and Paddle Type)
- ☐ B-75 Portable Mixers (Electric and Air Driven)

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Title_____

Company_____

Address_____

City_____ Zone____ State_____

DATA SERVICE

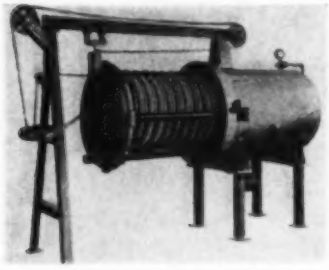
(*Continued from page 50*)

19 • *ULTRASONICS.* For supersonics a display of new laboratory hypersonic equipment. Unit for generating ultrasonic energy from electrical energy consisting of a generator, a transducer, hydraulic pump assembly and an accessory kit. Also a new transducer where high ultrasonic field strengths are not required. Electronic element available in standard frequencies from 400 to 1000 kc. Brush Development Co., Booth 662A.

20 • *CONVEYOFLOW.* For continuous weighing of dry materials and control of blends of dry and liquid ingredients, a display of conveyoflow on a continuous and batch basis. Working models of steam meters as well as propellor type main line water meters with recorders, mechanical recording meters, pneumatic and electrical systems for transmitting readings of flow, temperature, pressure and weight to secondary receivers. A 6000 lb./day chlorinizer-chlorine gas feeder will also be shown. Builders-Providence, Inc., Booth 493.

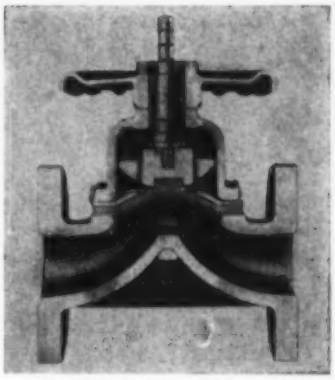
21 • *LIQUID METERS.* Single-piston volumetric meters for measuring liquids, hot water, gasoline, solvents, and chemicals. Available in bronze or stainless steel. Registers for integrated totals, batch measurement, and automatic cycling operations. Buffalo Meter Co., Booth 728.

25 • *LIFT-PLUG VALVES.* Non-lubricated lift-plug valves for corrosive chemicals and light hydrocarbons. Includes a separate and removable seat. These can be put on round opening and rectangular models, in sizes ranging from 2" to 12". Operating pressures from 50 to 5000 lbs./sq.in. and temperatures from −60 to 1800° F. Designed originally for hydrofluoric acid alkylation units. Cameron Iron Works, Inc., Booth 661.



Niagara filter designed for recovery of semi-dry solids.

. . . going to the show? . . . then use the Data Service as a guide . . . read our brief descriptions and talk to the company representatives at the show—and if you can't see all you planned—use our card to bring it to you in the mail.



Grinnell-Saunders valve with a Kel-F diaphragm.

. . . too busy to go? . . . use these cards to bring to your desk the data you want on the many new products described at the exposition. Complete your data files with information on the new tools of chemical engineering.

Mail card for more data➡

"C.E.P." EXPOSITION DATA SERVICE

I would like more information on the items described under the numbers I have circled.

1	2	3	4	5	6	7	8	9	10	10A	11	12	14	15	16	17
18	19	20	21	25	25A	26	27	28	29	30	31	32	33	35	36	37
38	38A	39	40	41	42	43	44	45	47	48	49	50	51	52	53	54
56	57	58	58A	59	60	61	62	63	64	65	66	67	68	71	72	73
74	75	77	78	79	80	82	83	83A	84	85	86	87	87A	88	89	90
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127	128	132	133	135	137	138	139	140								

PLEASE PRINT OR TYPE

Name _____ Position _____

Company _____

City _____ Zone _____ State _____

1 *November 1951*

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1	2	3	4	5	6	7	8	9	10	10A	11	12	14	15	16	17
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38	38A	39	40	41	42	43	44	45	47	48	49	50	51	52	53	54
56	57	58	58A	59	60	61	62	63	64	65	66	67	68	71	72	73
74	75	77	78	79	80	82	83	83A	84	85	86	87	87A	88	89	90
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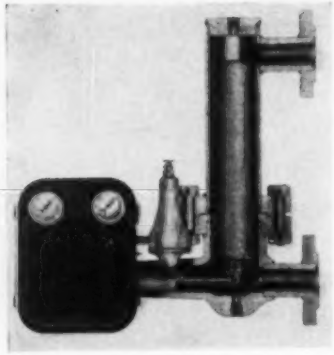
PLEASE PRINT OR TYPE

Name _____ Position _____

Company _____

City _____ Zone _____ State _____

2 *November 1951*



Liquid level controller of Black, Sivalls & Bryson.

25A • ***NEW ORGANICS.*** An exhibit of nine new organic compounds developed during the past year. Shown will be: alpha hydroxyl adip aldehyde; crag herbicide #1; 2 butyl, 2 ethyl propane diol 1, 3; 2,2,diethyl propane diol 1, 3; 1,2,6,hexane triol; triol 230; flexol plasticizers 2 GB and R 2 H; methyl ethyl pyridine. Carbide & Carbon Chemicals Co., Booth 17.

26 • ***COUNTER-CURRENT SOLVENT EXTRACTOR.*** A centrifugal solvent extractor combining several extraction stages. Extraction efficiency equal to three theoretical stages, capacities to 1300 gals. of liquid mixture per hour, bowl with a capacity of 17.2 gals., sludge space 5.6 gals. of precipitated solids. First time shown. Stainless steel bowl has a speed of 3800 rev./min. Centrico, Inc., Booth 813.

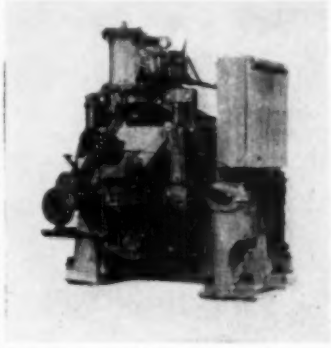
27 • ***DISTILLATION EQUIPMENT.*** Flow charts of distillation equipment made for the chemical industry. A large cutaway view of a new four-pass boiler. Cleaver-Brooks Co., Booth 709.

28 • ***VERTICAL SPEED REDUCER.*** A vertical worm gear speed reducer cutaway to show internal construction and design features. For cooling tower service. Uses tapered roller bearings on shafts and offers a range of speed reduction to meet fan requirements in cooling towers. Cleveland Worm & Gear Co., Booth 502.

29 • ***STEAM GENERATOR.*** A recirculation steam generator, animated display showing a vertical boiler unit. Will show controlled recirculation for either oil or gas burners, push button control specially designed for chemical processes requiring high pressure steam continuously or intermittently. Combustion Engineering-Superheater, Inc., Booth 266.

30 • ***CLARIFICATION.*** An operating model of a Fulflo filter with transparent plastic shell. Will show microscopic clarification of contaminated liquids. Synthetic fiber tubes give maximum resistance to corrosive attack. Commercial Filter Corp., Booth 499.

31 • ***PETROCHEMICALS.*** How Commercial Solvents Corp. has expanded in the petrochemical field. Showing of products manufactured and available with descriptive literature. Commercial Solvents Corp., Booth 55.



Sharples super dehydrator used in the new Sharples caustic soda process.

32 • ***CORROSION RESISTANT VALVES AND FITTINGS.*** Stainless steel valves, fittings, and castings for use in the chemical process industries where corrosion is a problem. Parts will be available for examination. A section of the exhibit of castings made by the company plus all types of screwed, welded, and forged fittings. The Cooper Alloy Foundry Co., Booth 565.

33 • ***CONVEYOR BELTING.*** Three types of belts for transportation of chemicals. A chain link, a flat wire, and a flex-grid. Cyclone Fence Division, Booth 76.

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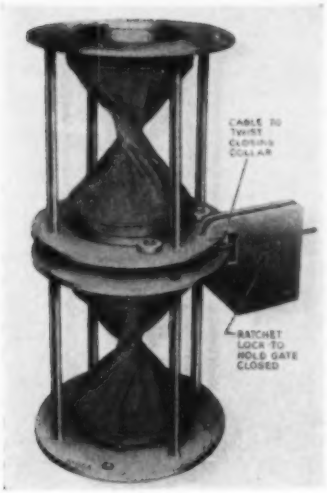

Stephens-Adamson Mfg. Co. Twistite double-closure Ben valves for solid materials.

35 • MILLS AND MIXERS. Small mills, mixers, silters, etc., showing operating principles of larger production models. Double arm mixers, gyrating silters, dispersion mills, pony mixers, blending mixers, etc., of use in the chemical processing, agriculture, paint, etc., industries. J. H. Day Co., Booth 718.

36 • CENTRIFUGAL SEPARATION. Featuring the "Nozzle-matic" to separate two liquids and simultaneously to separate continuously and discharge a high percentage of solids. Separator discharges divided solid matter and some heavy liquid through nozzles into the lowest of three discharge covers. The remainder of the heavy liquid discharges into the middle cover and the light liquid on the top. For various operations in the chemical field. Examples: separating fish oil from press liquor with constant removal of solids, recovery of citrus oil from peel water, stripping gluten from starch or removing the bulk of starch from gluten, recovery of wool grease, etc. DeLaval Separator Co., Booth 323.

37 • CLARIFICATION AND SO_2 PRODUCTION. A display of a 3" operating installation of the DorrClone, cylindrical-conical classification unit utilizing centrifugal force instead of gravity. Installation will illustrate capacity and separation characteristics. Also Dorrco fluosolid system for the production of high strength SO_2 gas from pyrite or pyrhotite. From a pyrite carrying 48-50% sulfur the gas strength will average 14-15% SO_2. Dorr Co., Booth 64.

38 • 38A • DUST CONTROL AND CONVEYORS. Automatic filters and multi-bag filters for industrial dust control. Will demonstrate via a transparent plastic insert an inside view of the operation of the dust filtering and cleaning cycles. (38A) Also a pneumatic conveyor for handling bulk free-flowing granular powdered materials. Dracco Corp., Booth 662.

39 • PLUG VALVE. Type F plug valve featuring no lubrication and no metal-to-metal contact. Body and plug of valve are manufactured of Durco corrosion alloys separated by a Teflon sleeve to provide sealing and lubricating surface. Available ¼-2" size. Duriron Co., Inc., Booth 19.

40 • EMULSION PUMPS. Positive displacement pumps in stainless steel or bronze featuring non-foaming conveyance and non-shearing pumping motion for handling delicate multiphase emulsions. Eco Engineering Co., Booth 641.

41 • VACUUM FILTERS. Drum, disc and top feed vacuum filters. Company also has precoat filters. Bulletin available with complete description. Eimco Corp., Booth 604.

42 • CONSTANT TEMPERATURE ROOMS. A constant temperature room to eliminate the need for several individual constant temperature cabinets. Company will have on display a walk-in constant temperature room assembled in 2 or 3 hours, for holding temperatures within 35 and 50° C. within ±1½°. Air changed every 5 minutes, accommodates 6 tiers of adjustable shelves. Two sizes of adjustable shelves. Two sizes available operating on 110 v. AC. Electric Hotpack Co., Inc., Booth 655.

43 • MAGNETIC COLLECTORS. Magnetic separators used for the chemical industry to remove iron and steel from process materials. Features magnetic pulleys, and magnetic pipeline trap for protection of liquid lines. Plate type magnets and a demonstration of the RCA utility metal detector, an electronic system for use on conveyor belts, conveyor chutes, etc. Eriez Mfg. Co., Booth 631.

44 • INDUSTRIAL INSTRUMENTS. A display of solenoid valves, gas analysis equipment of industrial type, thermocouple pyrometers with accessories, and fluid flowmeters electrically operated. Charles Engelhard, Inc., Booth 455.

45 • SEPARATORS AND GRADERS. A magnetic separator using gravity and a multiform grader. Grader comprises a series of screens vibrated in a horizontal plane by a reciprocating drive. Material is carried off through chutes, the undersize passing to the next screen. Magnetic separator uses a magnetic rotor, retaining the magnetic pieces with a greater tenacity than the non-magnetic. When the metal is thrown from the rotor face its trajectory is shorter than that of the non-magnetic particle material. Exolon Co., Booth 52.

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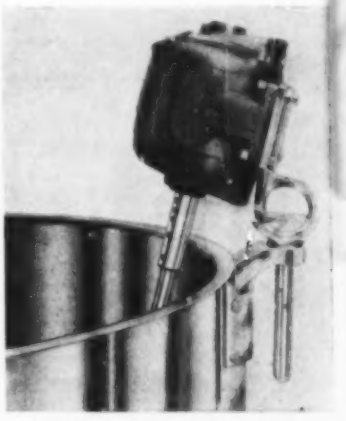
For most of the equipment described here, the manufacturers have available complete bulletins and catalogs.

47 • PANELS. Deep wing panels for holding instruments and controls. Self-supporting, side wings serve as support members. Can also be used to mount terminal blocks and other electrical and mechanical equipment. Falstrom Co., Booth 425.

48 • SAFETY-RELIEF VALVES. Chemical corrosion resistant safety-relief valves featuring two types of bellows construction designed for a maximum of safety. Samples of FarriSeal and BalanSeal bellows. Farris Engineering Corp., Booth 489.

49 • CENTRALIZED LUBRICATION. An exhibit and operating demonstration of centralized lubrication systems to enable engineers to study design and component parts of lubrication system for industrial equipment need-



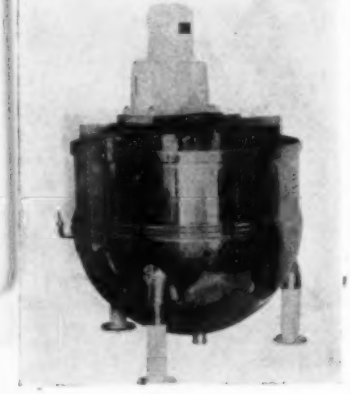
Swivel mixer of Alsop Engineering Corp.

ing periodic lubrication. Grease is distributed from one central pumping unit at controllable intervals. Farval Corp., Booth 502.

50 • 51 • 52. FILTRATION UNITS. Pilot plant filter of stainless steel, string discharge wash and compression mechanisms. String discharge removable for operation as conventional scraper discharge. Available under a rental plan. (51) Filtration fabrics of Vinyon N, Dynel, Orlon and nylon in a variety of weights and weaves. (52) Newly developed chemical resistant work clothing made of Vinyon N. Resists both acid and alkaline materials. Filtration Engineers, Inc., Booth 8.

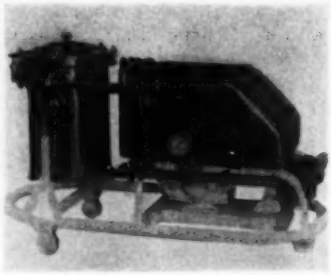
53 • GASKETS. A 7-foot model of a spiral-wound gasket illustrating spiral winding of V-crimped metal and filler plies. Will feature a new compression-gauge gasket with an inside ring and new Teflon-filled gaskets. Teflon is trapped between edges of metal and eliminates cold flow when bolting load is changed or temperature of the confined fluid changes. Flexitallic Gasket Co., Booth 806.

54 • LITHIUM AND ZIRCONIUM. A research and development display featuring lithium and zirconium, lithium being used in ceramics, grease, and lubricants, air conditioning, drying, pharmaceuticals, and fluxes for welding and brazing. Zirconium is featured as a pure ductile for bar, sheet, strip, etc., and in electronics as a gas absorber in vacuum tubes. Culmination of the 75th anniversary of the Foote Mineral Co., Booth 607.



Groen stainless steel kettle featuring the rota-therm jacket.

56 • 57 • GAS HOLDER AND ROTARY DRYER. The Wiggins gasholder which uses a dry seal, eliminates the maintenance and operation costs of wet, grease, and tar seal type gasholders. (57) A transparent model rotary dryer of the Louisville type H rotary direct heat dryer showing the action of the dryer on material passing through the unit. General American Transportation Corp., Booth 285.



Groen multipurpose filter for liquids. Precoat is deposited over vertical tubes of wire cloth.

58 • STRAPPING. For packaging and material handling, round steel wire. Equipment and accessories for binding packages from cartons to car lots. Gerrard Steel Strapping Co., Booth 76.

58A • GLASS-LINED REACTOR. A closed 200-gal. glass-lined reactor of standard construction, and a 2-gal. reactor designed for operating at 500 lbs./sq.in. Latter equipped with rotary mechanical agitator seals. Glascote Products, Inc., Booth 657.

59 • PERLITE. For industrial use a display of Grellex, a perlite for insulation, fillers, abrasives. Low electrical conductivity and vapor absorption. Specific heat 0.20 Btu/lb./°F. Thermal conductivity from 0.22 to 0.35. Great Lakes Carbon Corp., Booth 734.

60 • DIAPHRAGM VALVE. A demonstration of diaphragm valves equipped with Kel-F diaphragms (polytrifluorochloroethylene). Resistant to most chemicals. Power operated diaphragms also shown. Pressures up to 100 lbs./sq.in. and temperatures vary according to the fluids and pressures with a maximum to 250° F. recommended. Valves from ¾ to 4". Grinnell Co., Booth 251.

61 • 62 • KETTLES AND FILTERS. Vacuum kettles, steam jacketed kettles (61) with a rota-therm jacket for faster heating. (62) An all-purpose filter for liquids. Principle is that of flow through a precoated filter on a screen wire tubular filter unit. Groen Mfg. Co., Booth 805.

63 • WATER FILTRATION. A recently developed water filtration unit, which cleans itself automatically with no interruption of the filtering operation will be featured along with various equipment for pulverizing, drying, classifying, etc. Hardinge Co., Inc., Booth 60.

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By using the postage-free request card for the equipment described here complete literature will be mailed to you.

64 • CHEMICAL RESISTANT EQUIPMENT. Chemical equipment for the process industries featuring chemical resistance to corrosive substances. Strong acid heaters of impervious graphite. Lined pipe, a variety of lining materials from 1½" diam. up. Combination agitators for heating and agitating solutions, steam jet principle in lead, bronze and impervious graphite. Lined process tanks including rubber, Koroseal Saran and lead. Heil Process Equipment Corp., Booth 539.

65 • AIR MEASUREMENT. For measuring air velocity Alnor line of velometers and also a display of the same line of temperature measuring and controlling instruments, plus a dew point indicator. Illinois Testing Labs., Inc., Booth 38.

66 • CONDUCTIVITY INSTRUMENTS. Solution conductivity controller for ultra pure water which will measure specific resistance of water as high as 18 megohms. Armored conductivity cells for sulfuric acid for pipeline installation suitable for line pressures up to 500 lbs./sq.in. Industrial Instruments, Inc., Booth 410.

67 • THERMAL LIQUID BOILER. For heating Dowtherms, Aroclors, heat transfer oil, etc., a forced recirculation boiler operating at about 750° F. High velocity flow through tubes, gas fired, capacities from ½ to 2 million B.t.u./hr. International-La-Mont type, induced draft fan which eliminates stack construction. International Boiler Works Co., Booth 817.

68 • PUMPS. Inexpensive pumps, of stainless steel, bronze and cast iron, and featuring impellers of neoprene rubber. For use with all processing liquids. Pumps are gearless, self-priming with one moving part. Jabsco Pump Co., Booth 430.

71 • LABORATORY APPARATUS. A full-circle polarimeter, new in the United States, a micro-electrophoresis apparatus, a prismatic binocular microscope and drawing instruments by the Kern Co., Booth 218.

72 • RADIO ISOTOPE HOOD. For use with radio isotopes, a hood for industrial, hospital and educational institutions. Kewaunee Mfg. Co., Booth 308.

73 • VACUUM PUMPS. A line of vacuum and rotary liquid pumps. Small vacuum pump for laboratory and pilot plant projects, displaces 2 cu. ft. of air a minute. Another model displacement of 5 cu.ft./min. for industrial applications and research. Both pumps can produce 0.2 micron vacuums. Kinney Mfg. Co., Booth 468.

74 • COLOR COMPARATORS. A laboratory color comparator, Nessler tubes with a shadowless bottom and in readings stopper need not be removed. Prevents solutions from oxidizing. Kimble Glass, Booth 342.

75 • PROCESSING EQUIPMENT. A pictorial dispay of processing equipment, kettles, mixers, stills, etc., with a 200 gal. jacketed stainless steel mixing unit, with an anchor-type agitator for mixing solids with liquids. L. O. Koven & Brother, Inc., Booth 304.

77 • TABLET UNITS. Two machines for tablet use in the pharmaceutical field and an inspection unit which will process 240,000 tablets an hour with tablets automatically turned over for reverse side inspection. A tablet counter which will deliver a minimum of 3000 tablets per minute. The Lakso Co., Inc., Booth 515.

78 • PUMPS. Self-priming pump of new design capable of developing a high vacuum. Corrosion resistant alloys. A lined slurry pump for handling abrasive mixtures with the liner renewable, and a new liquid chlorine pump. Lawrence Machine & Pump Corp., Booth 567.

79 • CASTINGS. For the chemical process industries a display of castings corrosive and heat resisting in a large range of metals; chromes, 18-8, Worthite, etc.; centrifugal castings for dense homogeneous structures of primary interest in producing circular parts for valve seats, pump rings, etc.; and carbon and low structural cast alloys for heat resisting services up to 1150° F. Lebanon Steel Foundry, Booth 465.

80 • OVENS. A standard electrically heated cabinet-type pan dryer with cross-flow air circulation and forced ventilation. Packaged unit shipped complete ready for operation. Five different sizes. Available steam operation for drying powdered or granulated material, effervescent salts, tablets, ink, dye pigments, etc.; and a glass annealing oven which may be operated at temperatures up to 1200° F. for annealing scientific glassware, ampoules, vials, etc. Various sizes. Lydon Brothers, Inc., Booth 437.

82 • ANALYTICAL EQUIPMENT. pH meters, color matching equipment, color densitometers. Feature: a color matching skylight which provides a duplication of north sky daylight for visual color matching. Macbeth Corp., Booth 225.

83 • CENTRIFUGE. Merco B9 pilot plant size centrifuge. Concentrates and washes solids, recovers solubles, classifies particle size. Return flow principle explained. For separation of sludge from lube oil, classification of pigments, concentrating and washing chemical precipitates, etc. Merco Centrifugal Co., Booth 504.

83A • MINIPUMP. A small metering pump delivering 3 ml./hr. to 3200 ml./hr. at pressures of 1000 lbs./sq.in. For pilot plants and processes requiring exact minimum quantities of chemicals. Special control provides 20:1 range of adjustment. In addition other automatic chemical feed devices with pumps having stroke adjustment from 1-100% in each cylinder. Milton Roy Co., Booth 432.

84 • MIXERS. Industrial mixing equipment for the process industries including portable mixers, permanently mounted top and side entering mixers for open and closed tanks, plus pressure vessels, etc. Will show a new line of mixers up to 500 hp. Mixing Equipment Co., Inc., Booth 307.

85 • CHEMICALS. Display and illustrated applications of some 75 Monsanto chemicals in 15 different industries. Monsanto Chemical Co., Booth 722.

86 • LABELING AND FILLING. Various labeling and filling machines for use in the chemical, pharmaceutical industries for bottling, etc. Portable fillers also. MRM Co., Inc., Booth 638.

87 • PIPES AND TUBES. For power plant piping and tubing, condensers and heat exchangers, a special stainless steel has been developed for standard and special requirements. National Tube Co., Booth 76.

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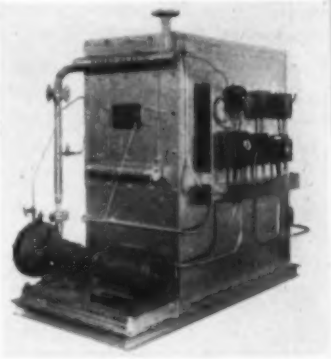
For most of the equipment described here, the manufacturers have available complete bulletins and catalogs.

87A • MIXERS. Mixing machinery, variable speed drives and a line of double motion drives will be shown, plus Nettco Flomix an "in the line" mixer to obtain mechanical mixing of liquids in a continuous process. New England Tank & Tower Co., Booth 50.

88 • GLUELESS LABELING. An automatic high speed labeling machine which uses a paper stock coated with a thermoplastic adhesive. Labels applied at the rate of 350 per minute. New Jersey Machine Corp., Booth 485.

89 • HORIZONTAL LEAF FILTER. A 36" diam. horizontal pressure-leaf filter for rapid discharge of semi-dry cakes. Features a quick-opening cover, integral leaf carriage exposing all leaves simultaneously for cleaning, and an integral supporting frame and windlass. Niagara Filter Corp., Booth 417.

90 • FILTERS AND PUMPS. Large scale models of many types of filters in continuous pressure and batch pressure groups. Also models of acid handling and slurring pumps. There will be a three dimensional slide pro-



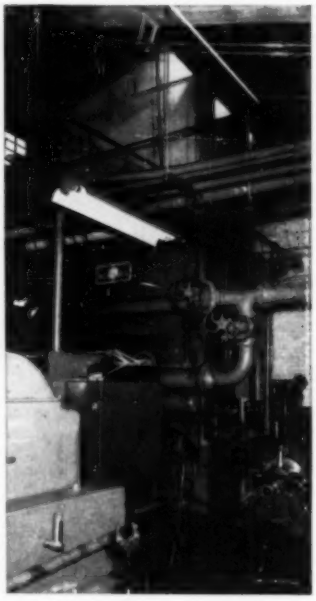
Gas fired thermal-liquid boiler of International Boiler Works. Has a capacity of 250,000 Btu./hr.

You Get Trustworthy Liquid or Gas Cooling With Great Cooling Water Savings from the NIAGARA AERO HEAT EXCHANGER

● You can cool air, gas, water, oils, chemicals, electric and power and process equipment, engines, mechanical processes with lower cost and really accurate control of temperature with the Niagara Aero Heat Exchanger.

You are assured of uniform, constant production and quality from any process . . . steady, reliable operation . . . lower cost for more dependable cooling. You can have closed system cooling with freedom from scale, dirt, corrosion and maintenance troubles. You can accurately cool more than one type of liquid with one machine.

The Niagara Aero Heat Exchanger uses atmospheric air to cool liquids and gases by evaporative cooling. You can remove heat at the rate of input to keep accurate control of gas or liquid temperature. You can put heat back into the system to save the losses of a "warm-up" period or to equalize the effect of load variations.



Great savings in cooling water and savings in piping, pumping and power return the cost to you quickly. The Niagara Aero Heat Exchanger can save you approximately 95% of your cooling water cost. Write for Bulletin 96.

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Over 35 Years Service in Industrial Air Engineering

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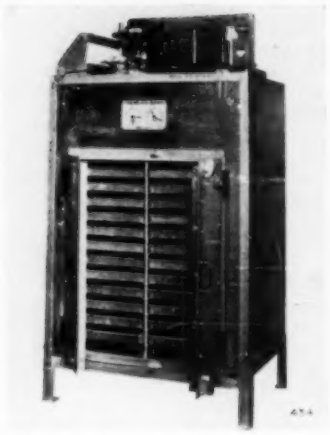
Experienced District Engineers in all Principal Cities



Lydon Brothers electrically heated cabinet type pan dryer.

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Data service is the monthly feature in Chemical Engineering Progress. Use it to keep up to date with what manufacturers are producing and offering to the chemical engineer.

jector to show other types of filters made by the company. Oliver United Filters, Inc., Booth 66.

91 • *DRY CHEMICAL FEEDERS.* Dry chemical feeders and a liquid feeder controlled from another booth, demonstrating the feeding of a liquid in direct proportion to the flow of dry material on a conveyor belt. Omega Machine Co., Booth 493.

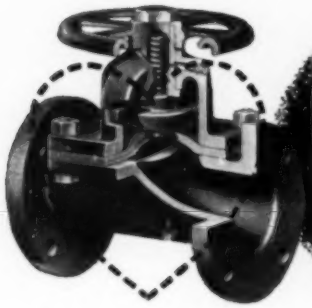
92 • *CHEMICAL INTERMEDIATES.* A full line of chemicals stressing mainly detergent raw materials, intermediates, lubricating oil additives, polybutenes, para, meta and ortho xylenes, plus several new products in the development stage. Oronite Chemical Co., Booth 711.

93 • *KAYLO INSULATION.* Hydrous calcium silicate insulation for pipes, curved blocks, flat blocks, insulating roof tile, firedoors, etc. Effective to temperatures up to 1200° F., pipe insulation for pipe diameters from ½ to 72" and tubing down to ¼". Curved block in various dimensions. Owens-Illinois Glass Co., Kaylo Division, Booth 401.

94 • *FILLING MACHINES.* Filling machines for collapsible tubes and jars for cans, bottles, etc. Features a self-

(Continued on page 60)

for the heart of the Saunders Patent Valve . . .



Hills-McCanna offers a complete selection of diaphragm materials to best suit your individual requirements

Code Number	Base	Stock Type	Service Quality
R-1	Rubber	Carbon Black	Acid/Alkaline, Heat Resistant
R-2	Rubber	Non-Carbon Black	High Acid/Alkaline Resistant
R-3	Rubber	Carbon Black	Non-Fat Food Service
R-4	Rubber	Carbon Black	Special Non-Contaminating
R-5	Rubber	Non-Carbon Black	Acid/Alkaline, Abrasion Resistant
N-1	Neoprene	Carbon Black	Acid/Alkaline/Oil/Heat Resistant
N-2	Neoprene	Carbon Black	Fat Food Service, Non-Contaminating
N-3	Neoprene	White	Special Non-Contaminating
H-1	Hycar	Carbon Black	Acid/Oil/Heat Resistant
K-1	Butyl	Carbon Black	Acid/Heat Resistant
T-1	Tygon	Carbon Black	Acid Resistant
C-3	Compar	Carbon Black	Solvent Resistant
L-1	Special Polyethylene	White	Acid Resistant (66° Be Sulfuric)
M-1-25	Kel-F	Non-Carbon Black	High Acid/Alkaline Resistant

In over 15 years of supplying Saunders Patent Diaphragm Valves to the processing industries, we have developed an extensive background of experience in the recommendation of the proper diaphragm material to meet a given set of conditions. This experience proves that only with diaphragms especially selected for your needs can you get the *best* service from your diaphragm valves. The wide range of diaphragm materials and their basic characteristics are shown in the table above. Each of these has advantages and limitations—no one is a cure-all—and the secret of successful selection of the right diaphragm is a thorough knowledge of these advantages and limitations.

Here at Hills-McCanna, recorded in the service records, is the experience that has resulted from valving over 2500 substances. This data is constantly being brought up to date to take into consideration the development of new diaphragm materials such as polyethylene and Kel-F. To any user of Hills-McCanna Valves, this record assures you of having the knowledge gained from thousands of other installations working for you.

Whatever your valving requirements, if they involve handling corrosive substances, slurries, semi-solids or other hard-to-handle fluids, we would welcome the opportunity to go over your needs with you. Hills-McCanna Diaphragm Valves are available in sizes from ⅜" to 14" handwheel or lever operated or arranged for automatic or remote operation. Choice of 14 diaphragm materials, 48 body materials. Write for descriptive literature. HILLS-McCANNA CO., 2438 N. Western Ave., Chicago 18, Illinois.

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saunders patent

diaphragm valves

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Force Feed Lubricators • Magnesium Alloy Castings

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That's because Dow Corning Antifoam A kills foam faster and in a wider variety of foamers than any other material known. Practically odorless, tasteless and non-toxic, it is safe to use in food and drugs at concentrations up to 10 parts per million—many times the concentrations normally required.

That kind of efficiency makes Dow Corning Antifoam A the most economical as well as the most versatile defoamer available.

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DATA SERVICE

(*Continued from page 58*)

expanding piston, a three-way valve. Either gravity or vacuum type bottle machine. Perl Machine Mfg. Co., Booth 644.

95 • *REACTOR EQUIPMENT.* Glass coated samples will show resistance to both acid and alkali under laboratory tests. Two new pieces of equipment will be shown—V-belt variable speed drive for reactor kettles, and drives equipped with new rotor seal, with water-cooled agitator and automatic counter balance, for protection against contamination. The Pfaudler Co., Booth 72.

Tablet counter of the Lakso Co. which counts a minimum of 3000 tablets a minute.

96 • *COOLING TOWER DRIVE.* Spiral bevel cooling tower drive which features efficiencies within the range of 97 to 98% insuring minimum power loss. Alloy steel forgings are used wherever advantageous. Built-in oil pump. Philadelphia Gear Works, Inc., Booth 78.

97 • *PHOTO-ELECTRIC EQUIPMENT.* Photoelectric and electronic instruments for use in analytical production and control. Colorimeters, fluorescence meters, exposure photometers, reflection meters, densitometers, etc. Also radiation-detection. Photovolt Corp., Booth 270.

98 • *FOAMGLAS.* An exhibit of foamglas and its uses in the insulation of pipe and process equipment. Pittsburgh Corning Corp., Booth 613.

99 • *PLATECOILS.* Heat exchangers of embossed metal sheets, 16 gauge metal, seams spot-welded to form compact units for circulating, under

(*Continued on page 62*)

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OF PROCESS EQUIPMENT KNOW HOW

now available in the U.S.A.

- Nitric Acid Plants
- Fertilizer Plants
- Ammonia Processing
- Natural Fats and Oils Processing
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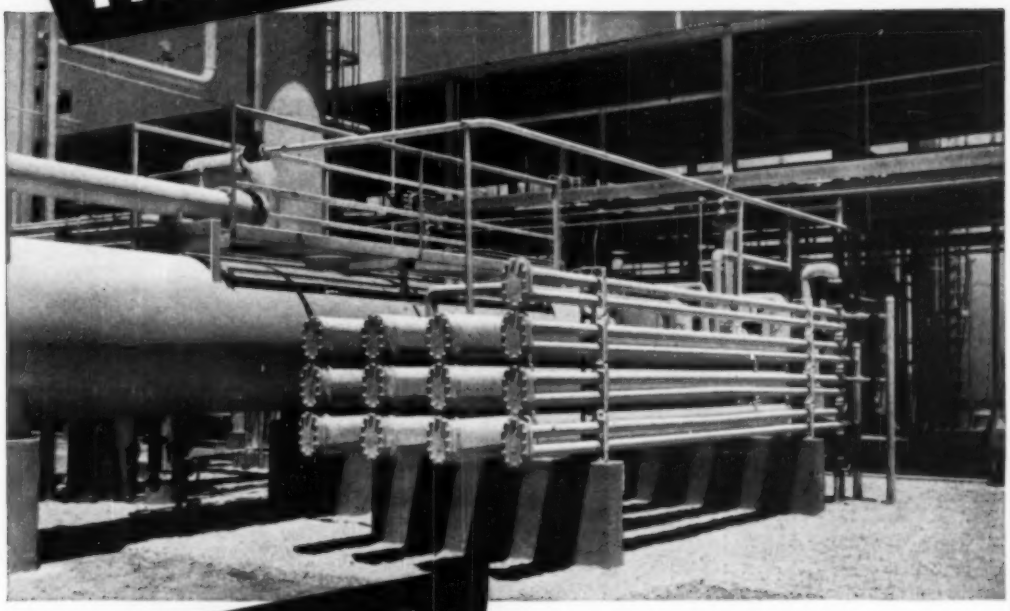

with **BROWN FINTUBE** *sectional hairpin heat exchangers*

● You'll get almost unlimited flexibility to meet changes in duties, plant re-arrangements, etc., with Brown Fintube Sectional Heat Exchangers. By simply adding a few sections to your existing exchangers, or removing a few sections, or changing the series-parallel manifolding, change-overs can be made easily and quickly. You can be operating ***efficiently*** on almost any new or different duty, on short notice, with a minimum of expense for new equipment, and without obsoleting any of your former facilities.

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Tank Suction and Line Heaters
Fintube Heaters for Bulk Storage Tanks
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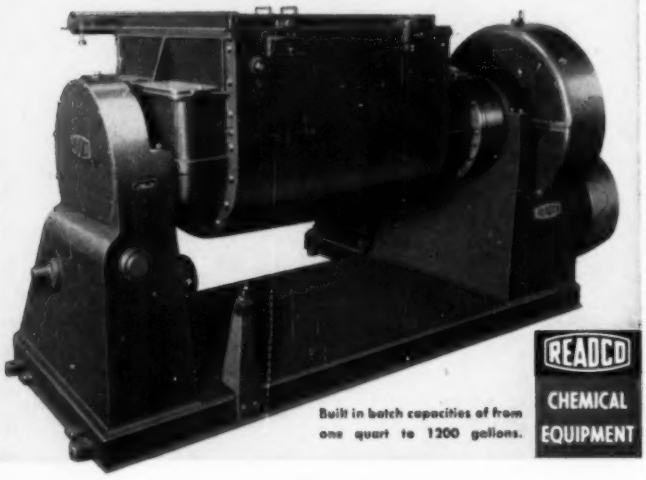
OVERLAPPING ACTION

designed for thorough–fast mixing



Built in batch capacities of from one quart to 1200 gallons.

READCO CHEMICAL EQUIPMENT

THE OVERLAPPING arm action of Readco Double Arm Mixers exposes new surfaces and breaks down the entire mass with each rotation. It produces a homogeneous mass in a short mixing cycle. Cylinders of material cannot form around the arms. Peak loads are eliminated.

Close clearances between mixer arms and shell provide better heat transfer and thorough mixing.

All gears operate in oil, assuring positive lubrication at all times.

Readco Double Arm Mixers feature: anti-friction bearings, adjustable bowl covers, single packing gland construction, easily removed split seals.

Options: Vacuum or non-vacuum, jacketed or non-jacketed design... single, multi-speed, or variable-speed drives... tilting bowl or bottom discharge... construction of carbon steel, stainless steel, or any commercial alloy. *Read Standard Corporation, Bakery • Chemical Division, York, Pennsylvania.*

FORMERLY Read Machinery Division of The Standard Stoker Company, Inc. ONLY THE NAME HAS CHANGED.

READ STANDARD CORPORATION

(*Continued from page 60*)

pressure, heating or cooling media. New designs and materials, stainless, cold rolled, Heresite coating, stainless electro-polished, and stainless steel ground and polished. High heat transfer rates. Claim is smaller unit, easily changed and cleaned, over conventional pipe testers, etc. Platecoil Division of Kold-Hold Mfg. Co., Booth 707.

100 • PNEUMATIC CLASSIFIER. A laboratory twin-cone fractionator for pilot plant separation of finely ground materials according to particle size. Operate on a 110 v. circuit, can handle up to 100 lbs./hr. of material weighing from 75 to 100 lbs./cu.ft. Consists of two pneumatic classifiers built into one unit. Material separated into two sections—one fine, the other coarse, coarse material reclassified with subsequent gain of 10% of the fines. Also a rotary airlock feeder used in pneumatic conveying systems and also as a volumetric feeder from bins, hoppers, etc. Prater Pulverizer Co., Booth 490.

101 • DRY FREEZE UNIT. Dryer for freeze drying heat sensitive materials such as biologicals, chemicals and foods. Essentially a horizontal cylindrical chamber for drying under vacuum, a refrigeration system and a freezer cabinet. Proctor & Schwartz, Inc., Booth 15.

102 • GRAVIMETRIC FEEDING UNIIT. A flow responsive gravimetric feeding unit for continuous addition of treating chemicals in process operations. Handles primary flows up to 5000 gals./min. with carrying capacities up to 5000 lbs. Also, a constant rate continuous volumetric proportioner for blending two or more components. A micro-feeder with 100 cc. capacity cylinder, gives feed at rates of 0.1 to 10 cc./hr. against pressures up to 2000 lbs./sq.in. "Proportioneers Inc." Booth 477.

105 • ELECTRONIC METAL DETECTOR. An electronic metal detector, various models, for detecting metal particles in meats, bakery and candy products, etc. Shown too, industrial television, high frequency heating equipment, and a new table type permanent magnet electron microscope. Radio Corporation of America, Booth 633.

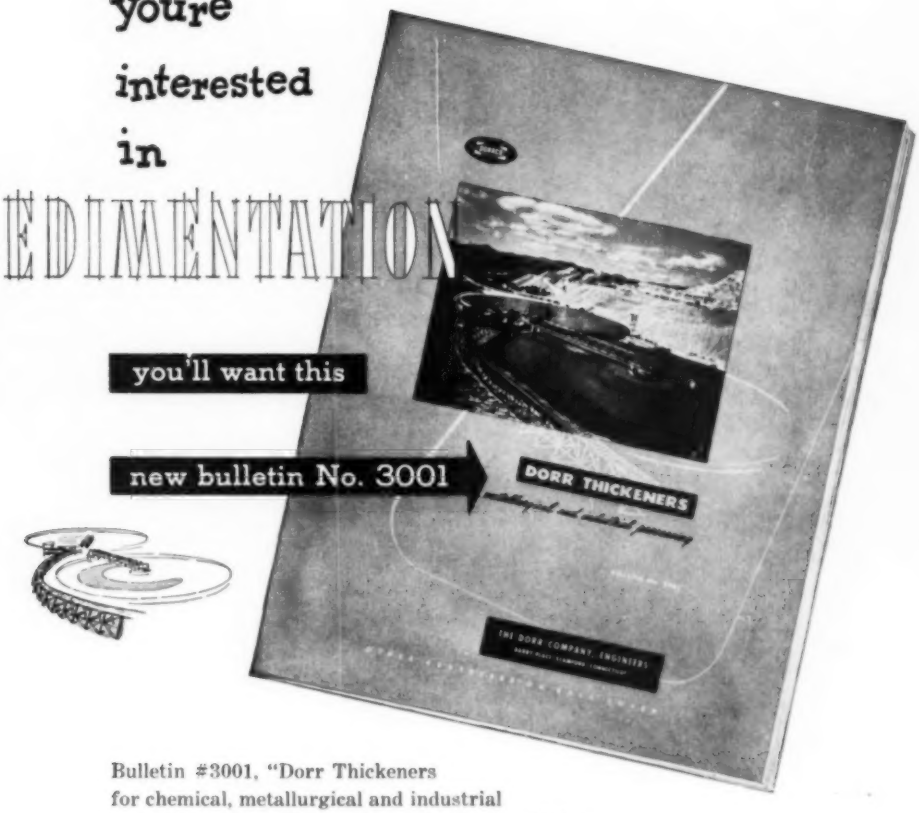
106 • SPEED CONTROL. For infinitely variable speed control three pieces

(*Continued on page 64*)

if you're interested in SEDIMENTATION

you'll want this

new bulletin No. 3001



Bulletin #3001, "Dorr Thickeners for chemical, metallurgical and industrial processing" has just come off the press. Containing 28 pages of descriptions, drawings and photographs, it covers the comprehensive line of Dorr Thickeners briefly and factually. If you're concerned with thickening problems and the equipment with which to solve them, you'll find it helpful. Write for your free copy today.

We'd like to show you some of our newest developments at the 23rd Exposition of Chemical Industries at Grand Central Palace in New York, November 26 to December 1. We'll be glad to see you at Booths 64 and 65 on the main floor, any time during the Show.

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DON'T GUESS about steam flow. Whether you're selling steam or buying it, producing it or distributing it, BUILDERS SHUNTFLO STEAM METER gives you the steam flow **facts** needed to save your steam dollars. This self-contained meter is driven by the steam in the pipeline itself. With a direct-reading Shuntflo Meter in the line, you know exactly how many pounds or cubic feet of steam is consumed . . . accurate within ± 2% under most conditions.

This meter is easy to install, easy to service, easy to modify for changed capacity. Model SMKS (shown) is furnished for 2" to 14" lines: Model SMDH for 1" and 1½" lines. It will pay you to learn more about Builders Shuntflo, the meter that's first choice with public utilities, district heating companies, industries, and commercial buildings of all types. For Bulletins 400-F1 and 400-F2, address Builders-Providence, Inc. (Division of Builders Iron Foundry), 419 Harris Avenue, Providence 1, Rhode Island.

BUILDERS makes a complete line of flow meters and controllers for liquids, steam, air, gas, and dry materials . . . . mechanical and differential . . . including The Venturi Meter and Chlorinizers (chlorine gas feeders).

BUILDERS PROVIDENCE *Instruments*

BIF INDUSTRIES

BUILDERS

DATA SERVICE

(*Continued from page 62*)

of equipment, including a variable speed transmission, vari-speed motodrive, vari-speed motor pulleys, varispeed junior pulley and a fractional hp. varispeed motodrive. Motodrive is available in six sizes, capacities from ¼ to 20 hp., speed ratios of 2:1 to 10:1. Reeves Pulley Co., Booth 34.

107 • MOTORS AND DRIVES. A-c motors and V°S drive. Will include an operating, totally enclosed fan-cooled motor; a cutaway showing the inside of an A-c motor, and 3 A-c motors each showing different types of conduit arrangement. An electronic and a rotating Reliance V°S drive will be available to operate. Reliance Electric & Engineering Co., Booth 26.

108 • STAINLESS STEEL. An exhibit of equipment made for the chemical industry out of Republic enduro stainless steel. Republic Steel Corp., Booth 434.

109 • 110 • DISINTEGRATOR AND THERMASCREW. Angle disintegrator in pilot plant size on display an extension of the standard line of vertical disintegrators used for size reduction on both wet and dry materials from fine to coarse grinding. Disintegrator easily cleaned used where maximum degree of sanitation or purity is required. (110) The Thermascrew is also shown in the small laboratory size equipment standard line. Used for continuous heating, cooling, and drying services on dry and wet material. Mixes as well as functioning as heat exchanger. A continuous screw type conveyor with a hollow shaft and screw and a jacketed coil. Heating or cooling medium is circulated through the hollow portions while material passes through trough. Rietz Mfg. Co., Booth 648.

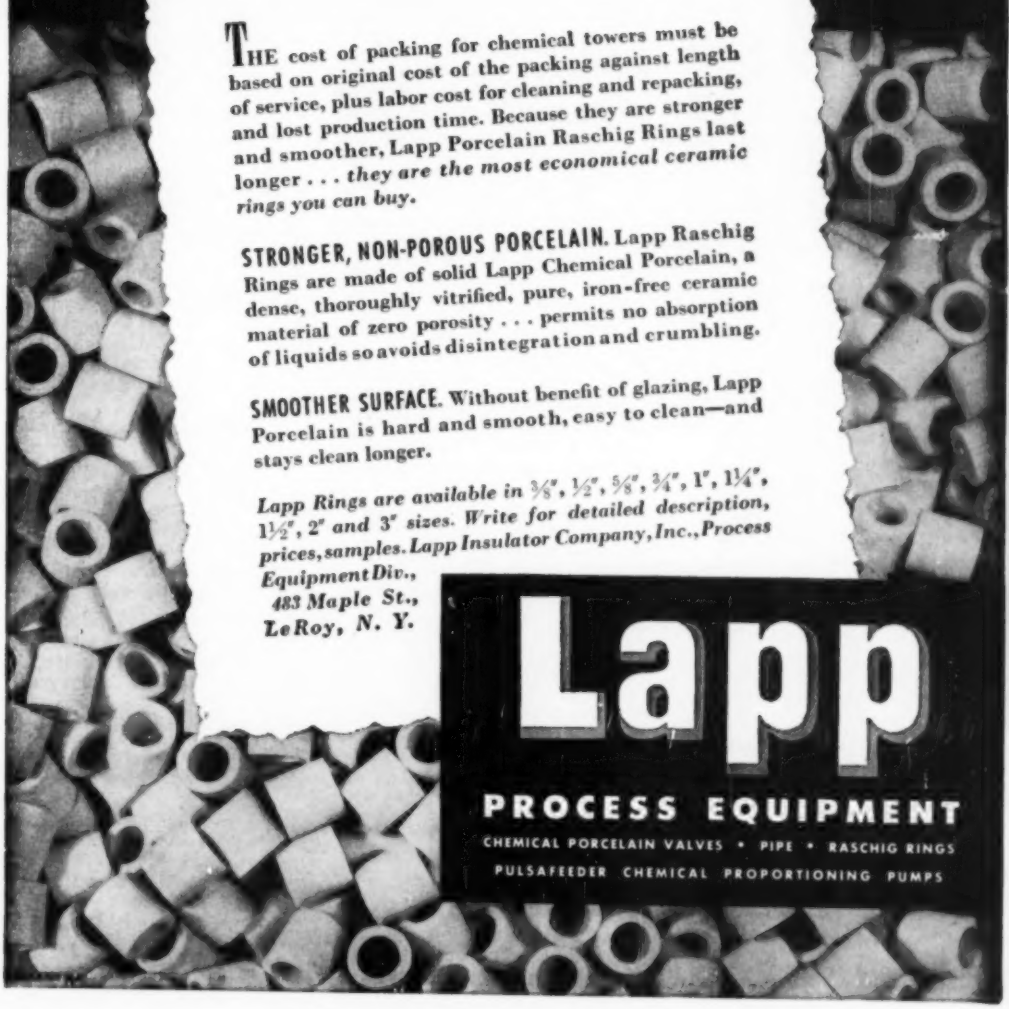
111 • PLUG VALVES. A display of Nordstrom lubricated plug valves in various metals including semi-steel, stainless steel, nickel, bronze, etc. Rockwell Mfg. Co., Booth 61.

112 • MIXING AND GRINDING. Pilot plant and laboratory scale size mixing and grinding equipment indicative of larger units. A double bladed kneading and mixing machine, three-roller mill, a miniature of a heavy paste mixer. Charles Ross & Son Co., Booth 407.

(*Continued on page 66*)

their LONG LIFE *makes* LAPP PORCELAIN RASCHIG RINGS

the most economical tower packing you can buy



THE cost of packing for chemical towers must be based on original cost of the packing against length of service, plus labor cost for cleaning and repacking, and lost production time. Because they are stronger and smoother, Lapp Porcelain Raschig Rings last longer . . . *they are the most economical ceramic rings you can buy.*

STRONGER, NON-POROUS PORCELAIN. Lapp Raschig Rings are made of solid Lapp Chemical Porcelain, a dense, thoroughly vitrified, pure, iron-free ceramic material of zero porosity . . . permits no absorption of liquids so avoids disintegration and crumbling.

SMOOTHER SURFACE. Without benefit of glazing, Lapp Porcelain is hard and smooth, easy to clean—and stays clean longer.

Lapp Rings are available in 3/8", 1/2", 5/8", 3/4", 1", 1 1/4", 1 1/2", 2" *and* 3" *sizes. Write for detailed description, prices, samples. Lapp Insulator Company, Inc., Process Equipment Div., 483 Maple St., LeRoy, N. Y.*

Lapp

PROCESS EQUIPMENT

CHEMICAL PORCELAIN VALVES • PIPE • RASCHIG RINGS

PULSAFEEDER CHEMICAL PROPORTIONING PUMPS

INVESTIGATE THE

Turbo-Dryer®

. . . gentle handling in drying — through repeated piling and spreading.

. . . repeat orders from nationally known concerns testify to its merits.

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Towers, Pressure Vessels and General Plate Fabrication manufactured with trained personnel and up-to-date equipment. Our Engineers will assist in designing to meet your requirements.

Good Design — Right Material — Expert Workmanship at a Fair Price.

HEAT EXCHANGERS A SPECIALTY

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Use our valuable new Bulletin as a handy reference guide . . . contains partial analysis of 1950 A.S.M.E. Code for Unfired Pressure Vessels.

DOWNINGTOWN IRON WORKS, INC.
DOWNINGTOWN, PA.
STEEL & ALLOY PLATE FABRICATION
HEAT EXCHANGERS

DATA SERVICE

(*Continued from page 64*)

113 • ***PUNCH CARD SYSTEMS.*** An exhibit of punch cards as applied to engineering and chemical research, especially the sorting of infrared data. Samuel P. Sadtler & Son, Inc., Booth 829.

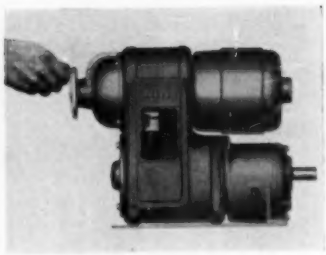
114 • ***SARAN LINED FITTINGS.*** Saran lined steel pipe fittings and valves, Saran pipe and tubing, and a Saran lined centrifugal pump. Saran Lined Pipe Co., Booth 460.

115 • ***DUST AND FUME COLLECTORS.*** A wet method of controlling dust and fumes, operating on a counter-flow principle providing contact between the contaminated air or gas stream and the recirculated liquid at low pressure. Liquid enters the unit near the top through full sized pipe opening down a column having four stages of stationary impingement vane surfaces. Claude B. Schneible Co., Booth 421.

116 • ***PACKING AND DISTILLATION.*** A display of a Cannon protruded type distillation packing which has a high percentage of free space, high flood rate, etc. Also on display will be a constant temperature bath, a distillation column, viscometers and thermoregulators. Scientific Development Co., Booth 812.

117 • ***HYDROPULSE.*** A homogenizer which features rapid cleaning, no cylinders or pistons. Acts through alternate suction and pressure cycles obtained by pulsators actuated by hydraulic pistons. From 1 to 5 hp. models, maximum pressure up to 3000 lbs./sq.in. Scott & Williams, Inc., Pioneer Division, Booth 801.

118 • *119* • ***CENTRIFUGALS.*** Centrifugals of various types in the Sharples line. Super-D-Hydrator for recovery and dehydration of crystals, Super-D-Canter a high capacity centrifuge for the removal of solids from liquids, clarification of liquids or classification of solids, nozljector which discharges solids continuously from a disc type bowl and is used for separation of two immiscible liquids containing solids. A Presurtite super centrifuge totally enclosed, for centrifuging liquids which produce volatile, or toxic vapors. (119) Caustic soda process. An exhibit of 16 slides illustrating a new continuous cycle of operation of a Super-D-Hydrator for the hydration of crystals from a new Sharples caustic soda process: flow diagram will show method of producing salts with low caustic content. Sharples Corp., Booth 58.



Reeves fractional Hp Vari-speed Moto Drive.

120 • ***FILTER EQUIPMENT.*** A filter press and diaphragm pump displaying operating principles. Also a Shriver Hydro-Kloser, hydraulic closing mechanism to close filter presses. T. Shriver & Co., Booth 12.

121 • ***FEEDING CONVEYORS.*** An exhibit of various feeders and conveyors using inertia type drive mechanism for feeding materials from bins at a regular controlled rate and keeping material in bins active to eliminate bridging. Simplicity Engineering Co., Booth 706.

▲

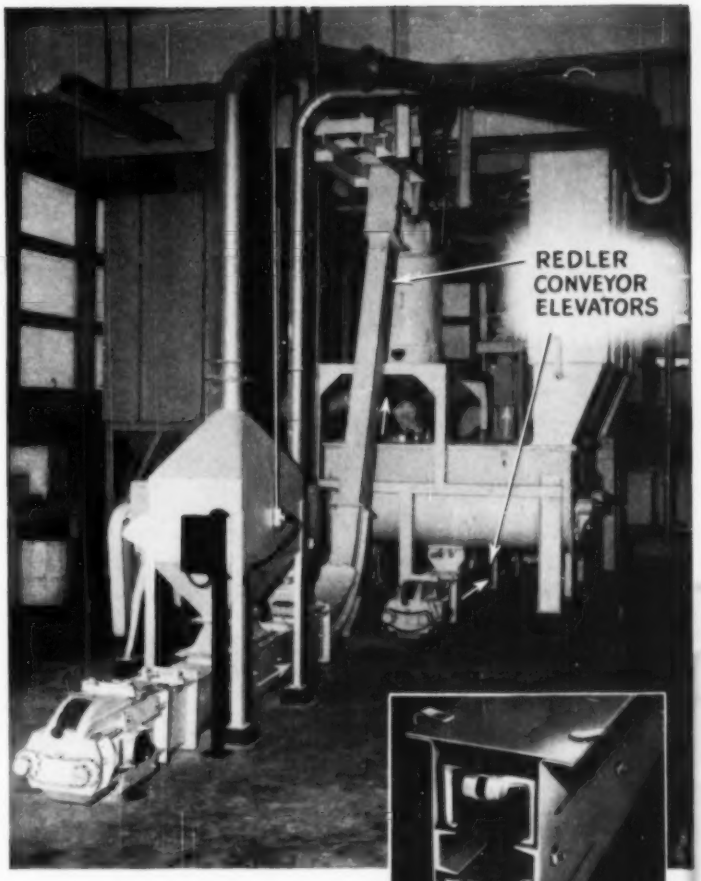
Use this service to bring to your desk the literature which you fail to see or get while at the chemical show.

122 • ***DUST FILTERS.*** Cloth bag type dust filter, having 484 sq. ft. of filter cloth to handle up to 1200 cu. ft. of air per minute. Complete with support, hopper, continuous discharge valve, fan and fan motor. W. W. Sly Mfg. Co., Booth 487.

123 • ***PNEU-VAC.*** A display of a Pneu-vac in operation, conveying ground corncob around the booth. Center of the display will be 250 sample jars of various materials processed on Sprout, Waldron equipment, along with a case history on each material. Sprout, Waldron & Co., Inc., Booth 550.

124 • ***LABORATORY SPECIALTIES.*** Laboratory specialties such as micropipettes, automatic pipettes, spectrophotometers, Ph meters, thermostat control ovens, incubators, etc. Standard Scientific Supply Corp., Booth 618.

(*Continued on page 68*)



4 Powder Handling Problems that found One Answer

...a REDLER Conveyor-Elevator System

The materials handled in bulk at this plant are talc, face powder and talcum products which imposed these special requirements: Bulk handling equipment to fit limited space—Dust-free conveying—Protection against contamination—Lowest handling costs. A REDLER installation, that fits neatly and snugly, and completely encloses the moving material was the perfect answer to all requirements.

Because of their great flexibility in design and adaptability to space, REDLER Conveyor Systems settle many such problems for plants of widely differing operations. Designed and built by S-A engineers, they provide fast, convenient handling for many materials with maximum safety and economy. S-A engineers will gladly talk over your requirements and offer helpful suggestions based on 50 years experience in conveying bulk materials.

Cross-section of standard Redler casing shows material moving in lower tier—flights returning, circuit-fashion, in upper.

CRUSELLAS Y COMPANIA, S. A.
Havana, Cuba

Two REDLER Conveyor-Elevators handle the full output—each serving as a feeder, conveyor and elevator in a single unit. Lower feed section (foreground of large photo) receives material from a feeder and elevates it for discharge to sifter. Sifted materials discharge into mixers from which they are drawn off by a second REDLER Conveyor-Elevator—then discharged to pulverizer and filled into batch boxes for delivery to packing operations. The dust-tight, enclosed REDLER casing keeps materials clean, safe and pure against contamination and avoids spillage.

1901-1951

50 years experience with bulk handling

STEPHEN S-A ADAMSON MFG. CO.

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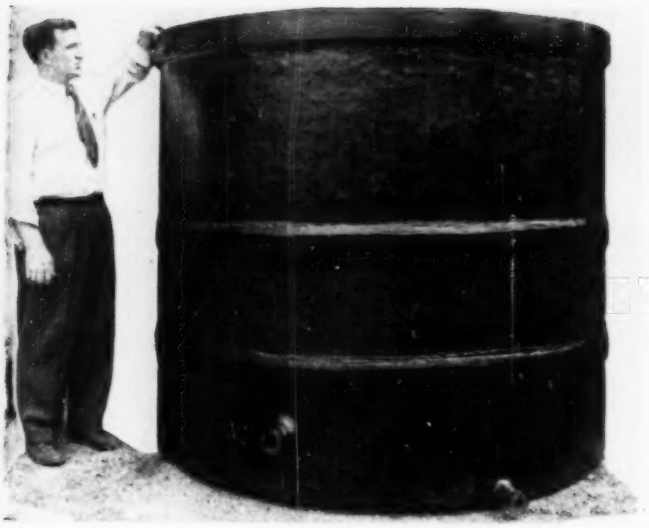
DESIGNERS AND MANUFACTURERS OF ALL TYPES OF BULK MATERIALS HANDLING EQUIPMENT



Strong, Light Weight, Corrosion Proof

PERMANITE EQUIPMENT

The Permanite constructed 1200 gallon tank above combines exceptional strength and light weight (1000 lbs.) with ease of installation and maintenance. It is totally inert to most corrosives including hot Muriatic acid to 230° F, HF, all alkalies, non-oxidizing acids and oils. Permanite can also handle organic solvent vapors to 300° F.

Permanite is a furan resin material reinforced with woven chemical glass fiber. It is strong, tough and highly corrosion resistant and is used:

As a structural material for complete functional units such as fume washers, HCl absorbers, towers and heat exchangers.

In molded one-piece units as sinks, trays, tanks, towers.

As a physical and thermal shock resistant armor for Knight-Ware Ceramic pipe, kettles, heat exchangers.

As light-weight pipe and fume ducts in diameters from 1½" to 36".

Permanite pipe can be machined, sawed and drilled. It may be installed with a minimum of support and is easily cut apart and joined in the field.

It will pay you to get all the facts on Permanite. Write for Bulletins No. 6F Permanite Equipment, No. 1F permanite Pipe and Ductwork, No. 7F Permanite HCl Absorbers.

See us at the New York Chemical Show, Booth 53

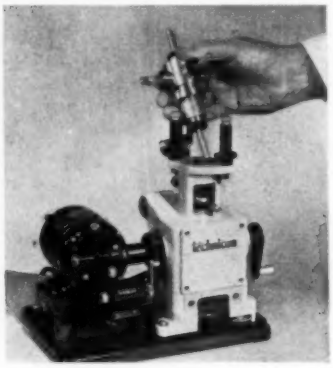
Maurice A. Knight 711 Kelly Ave., Akron 6, Ohio

Acid and Alkali-proof Chemical Equipment

DATA SERVICE

(*Continued from page 66*)

125 • ***TRANSMISSION EQUIPMENT.*** A display of conveyor belts, Twistite double-closure bin valves, roller type holdbacks, spring type belt cleaners, etc. Stephens-Adamson Mfg. Co., Booth 823.



Micro pump of Technicon Chromatography Corp. shows interchangeable cylinder.

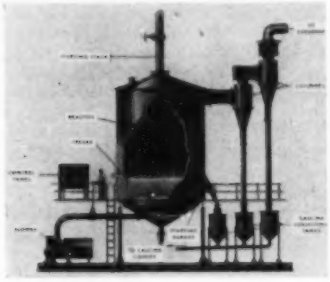
126 • ***VACUUM PROCESSING.*** Step by step operation of high vacuum processing equipment, including vacuum impregnators, metallizers, freeze dryers, rotary vacuum dryers, shelf dryers, microvac pumps and rotary seal pumps. F. J. Stokes Machine Co., Booth 80.

127 • ***MICRO PUMP.*** A micro pump for delivery of small volumes, 0.001 ml. up to 1 ml. per stroke, with an interchangeable chamber. Vernier setting controls volume delivered and two chambers for a range of volume deliveries available. Technicon Chromatography Corp., Booth 642.

128 • ***HOMOGENIZER DISPERSER.*** Laboratory and production models of a homegenizer disperser with three grinding faces. High speed, rotor space between rotor and stator which does the grinding is adjustable to the thousandths by hand wheel. Connections for heating and cooling of the stator face. Tri-Homo Corp., Booth 625.

132 • ***MOTORS AND SPEED TRANSMISSION.*** Three motors, a syncrogear, a doublenclosed and a sanitary for the chemical industries. The Syncrogear is an electrically geared motor of high torque and low speed; doublenclosed is an explosion-proof, dust-proof motor for dangerous locations; and the sanitary is for food and pharmaceutical processing. Also a varidrive, a variable speed trans-

mission that can be synchronized with production or the output capacity. U. S. Electrical Motors, Inc., Booth 609.



The Dorrco Fluosolids System as applied to sulfur dioxide production from pyrite.

133 • *COAL CHEMICALS.* A display of industrial and pharmaceutical chemicals, coal tar oils, and solvents. U. S. Steel Corp., Booth 76.

135 • *NEW PACKING.* A new ceramic type saddle packing, of light weight. Has greater surface area and less tendency to stack. Also a new cylindrical grinding medium, Burundum, for wet and dry grinding in paint, ceramic, chemical, etc., industries. A display of stoneware equipment used in chemical work. U. S. Stoneware Co., Booth 89.

137 • *PARAFLOW.* A thin plate heat exchanger takes operating pressures up to 120 lbs./sq.in. Supplied as standard in stainless steel—other metals available. Walker-Wallace, Inc., Booth 818.

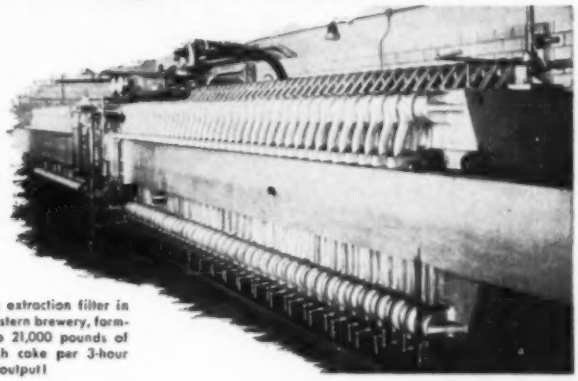
138 • *ELECTRICAL INSTRUMENTS.* A display of an Inductronic D-C amplifier for D-C measurement and control. An averaging resistance thermometer for determining average temperatures in storage tanks, grain bins, baking ovens, blending operations, etc. Weston Electrical Instrument Corp., Booth 263.

139 • *ELECTRICAL HEATERS.* Packaged automatic units for varying capacities for preheating fuel, heat transfer media, water, etc. 1 to 100 kw. Also a display of laboratory hot plates with variable control. Edwin L. Wiegand Co., Booth 601.

140 • *SOLVENT EXTRACTOR.* A 4" diameter pilot plant Scheibel extractor in operation. Otto H. York Co., Inc., Booth 380.

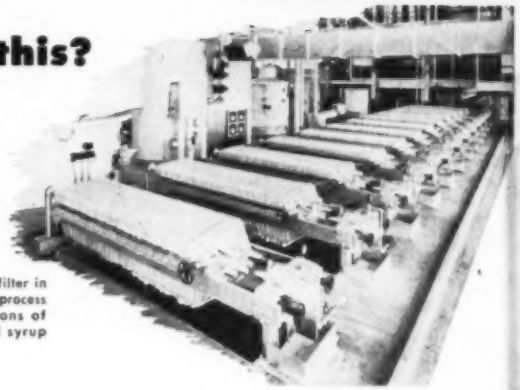
Need Filter Capacity

as big as this?



Double mash extraction filter in prominent Eastern brewery, forming 15,000 to 21,000 pounds of sparged mash cake per 3-hour cycle. That's output!

or this?



Each 60-chamber filter in this battery can process up to 2500 gallons of sugar juices and syrup per hour.

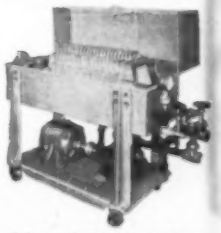
Whether your filter capacity requirements call for a few gallons of filtrate per batch or thousands of gallons of filtrate or tons of cake per hour—

Whether your material is easily filterable; or slimy, viscous or otherwise troublesome—

Whether it must be filtered at high or sub-normal temperature—or at pressures of 750 p.s.i. or more—

No matter how much or how little your production, you can get dependable filtration rates and quality at low operating cost if your equipment is a Shriver Filter Press. And the Shriver Catalog tells why. Write for it. T. Shriver & Company, Inc., 812 Hamilton St., Harrison, N. J.

or this?



This small portable, enclosed filter unit permits filtering and washing with any number of its 20 chambers.

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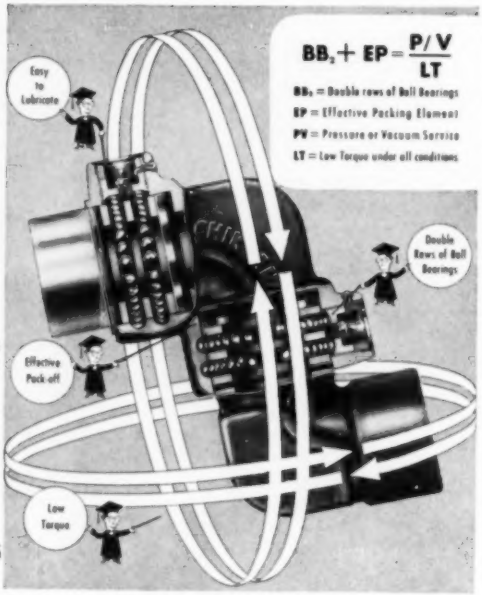
$BB_2 + EP = \frac{P/V}{LT}$
BB_2 = Double rows of Ball Bearings
EP = Effective Packing Element
PV = Pressure or Vacuum Service
LT = Low Torque under all conditions
Easy to Lubricate
Double Rows of Ball Bearings
Effective Pack-off
Low Torque

For over a quarter-century, here at CHIKSAN, we have specialized *exclusively* on developing and designing Swivel Joints* for all purposes . . . on manufacturing them to our rigid standards of precision . . . and on following through in the field to check performance under all sorts of conditions. That's why there is no substitute for CHIKSAN *Ball-Bearing* Swivel Joints* when it comes to efficient service with maximum safety . . . longest life . . . and minimum maintenance.

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CHIKSAN EXPORT CO. BREA, CALIFORNIA NEWARK 2, N. J.

BALL-BEARING SWIVEL JOINTS FOR ALL PURPOSES

CARBIDE SCHEDULES ALLETHRIN PLANT

Construction of a five- to six-million-dollar plant to produce allethrin, a new synthetic insecticide, was announced recently by Dr. J. G. Davidson, president of Carbide and Carbon Chemicals Co., a Division of Union Carbide and Carbon Corp. This new plant will be built in West Virginia.

Allethrin is a quick "knock-down" and killing agent used in insect sprays to replace pyrethrins, first announced last year (see "C.E.P.," Vol. 46, April issue, p. 24). Pyrethrins, imported chiefly from Africa, are being stockpiled for emergency military use. A certificate of necessity for this new plant was issued by the Defense Production Administration because of military and essential civilian uses for allethrin. The manufacture of allethrin here assures the United States of an adequate domestic source of this lower-cost insecticide.

Economies resulting from the large-scale production in the new plant will offer encouragement to expand present uses and to develop new applications, the announcement said. New synergists for allethrin, chemicals that will greatly increase its killing power are already in sight.

ALCOA EXPANDS RESEARCH FACILITIES

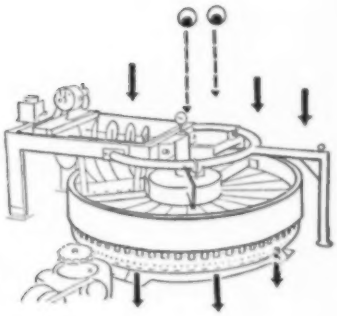
Aluminum Company of America is expanding its research facilities with the erection of a new building at the company's Aluminum Research Laboratories at New Kensington, Pa., according to Dr. Francis C. Frary, director of research.

The new unit will increase total floor space at the laboratories by about one third. Construction is already under way, and the building will be ready for occupancy early next year.

The new addition will consist of two bays, one of which will be three stories high, the other two stories. A six-ton mill-type crane will be installed in the first bay to handle heavy research equipment. Reinforced concrete will be used from the footings to the second floor level. Brick facing will be used from there to the top of the building to harmonize with other buildings on the laboratory grounds.

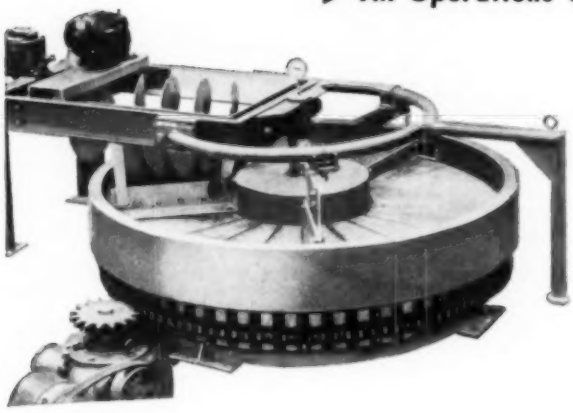
In addition to the main laboratory at New Kensington, Pa., the Company maintains laboratories at Massena, N. Y., Cleveland, Ohio, and East St. Louis, Ill. Massena investigates electrical problems; Cleveland handles foundry and forging problems; and East St. Louis works with aluminum ore products. The New Kensington laboratory deals with all research aspects of the aluminum industry.

OLIVER
HORIZONTAL
FILTER



▶ *All Flow Downward*

▶ *All Operations Visible*



YES, with the Oliver Horizontal Filter, gravity aids the flow at all times and the attendant can see what's going on. He's looking down on a horizontal surface and can watch the feed pour onto the filter and the cake form. He can get better washing because the wash has a more blanketing effect and is under better control. And, if desired, washes can be kept separate by means of the multi-outlet valves.

We are offering the Oliver Horizontal Filter as the fastest and highest capacity dewaterer or combination washer-dewaterer for a wide range of crystalline, mineral or fibrous products. Note the list of products being handled efficiently and economically on the Oliver Horizontal Filter. It is a constantly growing list.

We suggest you consider the Horizontal Filter for your problem if the products to be handled are in the general class noted: crystalline, mineral or fibrous. Bring your problems to us, anyway, even if they are not in this class, for we have many different types of filters from which to select. Our experience in filtration is very broad and goes back well over forty years.

Some Recent Horizontal Applications

Solvent Extracted Products
Ferrous Sulphate Crystals
from Titanium Sulphate Liquor
Precipitated Copper
Antibiotics
Silica Gel
Salt Tailings from Potash Recovery
Crude Sodium Chloride
Sulphur-Silica Concentrates

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Dorr g.m.b.h. Wiesbaden (16)
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Stamford, Conn.

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Melbourne

SOUTH AFRICA
E. L. Bateman Pty., Ltd.
Johannesburg, Transvaal

CANDIDATES FOR MEMBERSHIP IN A. I. Ch. E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions.

These names are listed in accordance with Article III, Section 7, of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Active Members will receive careful consideration if received before December 15, 1951, at the Office of the Secretary, American Institute of Chemical Engineers, 120 East 41st., New York 17, N. Y.

APPLICANTS FOR ACTIVE MEMBERSHIP

L. H. Brandt, *Baltimore, Md.*
Marriott W. Bredekamp, *Houghton, Mich.*
Frank E. Brewster, *Pittsfield, Mass.*
Paul G. Cater, *Baytown, Tex.*
Don Emery Cox, *Corpus Christi, Tex.*
Donald Holt Currie, *Wyandotte, Mich.*
J. M. Dauphin, *New Castle, Del.*
H. E. Dietrich, *Wilmington, Del.*
David E. Evans, *Baltimore, Md.*
Warren S. Ferguson, *Baltimore, Md.*
Franklin E. Ford, *Midland, Mich.*
Edwin A. Gaskill, Jr., *Baton Rouge, La.*
Frank L. Howard, *Spokane, Wash.*
R. E. Howard, *St. Louis, Mo.*
Gordon P. Hungerford, *Brooklyn, N. Y.*
Howard J. Jackson, *So. Charleston, W. Va.*
Webster N. Jones, Jr., *Marshallton, Del.*
S. W. Kapranos, *Clarendon Hills, Ill.*
Leon S. Kowalczyk, *Detroit, Mich.*
Robert W. Lange, *Boyertown, Pa.*
Charles G. MacDonald, *Baltimore, Md.*
R. M. Morris, *Springfield, Mass.*
Orin D. Myrick, Jr., *Baltimore, Md.*
James W. Pendorf, *Chicago, Ill.*
William M. Podas, *St. Paul, Minn.*
Harold R. Seykota, *Portland, Ore.*
Joseph D. Stett, *New Brunswick, N. J.*
Theodore Swenson, *St. Paul, Minn.*
Rolla W. Titus, *Marysville, Ohio*
Anton Vittone, Jr., *Charleston, W. Va.*
Charles Allen Walker, *New Haven, Conn.*
Robert C. Wheeler, *Argo, Ill.*
James Wilding, *Palo Alto, Calif.*
Norman H. Witte, *Decatur, Ind.*
Frederick C. Wood, *Wilmington, Calif.*
Edgar E. Wrege, *Carlsbad, N. M.*

APPLICANTS FOR ASSOCIATE MEMBERSHIP

Jack E. Lehman, *Lomita, Calif.*
Franklin A. Retzke, *Roselle, N. J.*

APPLICANTS FOR JUNIOR MEMBERSHIP

Robert A. Ackerman, *Rochester, N. Y.*
James W. Albus, *Chicago Hgts., Ill.*
Edwin C. Ashton, Jr., *Downingtown, Pa.*
Norman Avrutin, *Brooklyn, N. Y.*
R. F. Baddour, *Cambridge, Mass.*
Robert P. Bannon, *Oakland, Calif.*
Louis J. Basel, *Oak Ridge, Tenn.*
Norman D. Berman, *Wilmington, Del.*
Frederick C. Boss, *Harrisonburg, Va.*
Paul H. Bruce, *Gibsonburg, Ohio*
Bernard J. Byrne, *University Hgts., N. Y.*
Horace W. Chandler, *Brooklyn, N. Y.*
William F. Chenoweth, *Dayton, Ohio*
Anthony J. Cipolla, *Brooklyn, N. Y.*
Karl F. Cossaboon, Jr., *Wilmington, Del.*
Thomas W. Cundiff, *Terre Haute, Ind.*
Thomas E. Daly, Jr., *Ludlow, Mass.*
William E. Davis, *Binghamton, N. Y.*
John M. Dieter, *Argo, Ill.*
Ray H. Dovell, *Fort Lee, N. J.*
A. G. Duzsik, *Campbell, Calif.*
J. T. Dykes, *Windsor Mills, Que., Canada*
Ernest F. Ehmke, Jr., *Berkeley, Calif.*
Ralph F. Elmer, *Rochester, N. Y.*
Ben Entwisle, *Niagara Falls, N. Y.*
Richard C. Evans, *Ardmore, Pa.*
Frederick C. Franklin, *Tacoma, Wash.*
Joseph Paul Fris, *Richland, Wash.*
James O. Gaynor, Jr., *Morristown, N. J.*
John A. Georges, Jr., *Grasselli, N. J.*
Edward M. Germain, Jr., *Detroit, Mich.*
Lillian L. Golub, *Syracuse, N. Y.*
Richard H. Goodell, *Baton Rouge, La.*
David C. Haring, *Dayton, Ohio*
C. J. Hickman, *Argo, Ill.*
Philip C. Horsting, *New Hyde Park, N. Y.*
Marshall L. Hyman, *Cleveland, Ohio*
Wilbur B. Johnson, *Edge Moore, Del.*
Michael M. Kahn, *Nutley, N. J.*
James B. Kaye, *Collinsville, Ill.*
Charles W. Keeler, *Oak Ridge, Tenn.*
Lloyd W. Legacy, *Buffalo, Minn.*
Roy G. Lucas, *Wilmington, Del.*
Arthur M. Magnuson, *Carrollton, Ohio*
Hugh G. Martin, *McKeesport, Pa.*
D. Martin Del Campo, *Mexico, D. F., Mex.*
John D. McIrvine, *Madison, Wis.*
Robert McMurtrie, *Cambridge, Mass.*
Paul A. McNulty, *Bound Brook, N. J.*
John H. Mudge, *Pocatello, Idaho*
L. Paul Newton, *Kalamazoo, Mich.*

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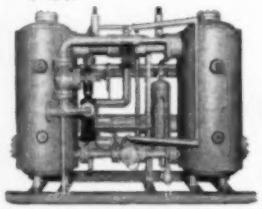

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SECRETARY'S REPORT

S. L. TYLER

THE Executive Committee of the Institute met at the Institute office in New York, Oct. 12. Bills for the month of October were approved for payment and the Minutes of the Executive Committee meeting of Sept. 16 were approved. The Treasurer's report was received and approved; it showed the Institute to be in an acceptable financial condition. All applicants for membership whose names appeared in the September Issue of Chemcial Engineering Progress were approved for election to the grade of membership indicated, since no adverse votes were received.

Several new student chapter counselors were appointed as follows: Homer Johnson at the University of Tennessee to succeed R. M. Boarts; J. H. Bilbrey at the University of Maryland to succeed C. R. Landgren; R. K. Finn at the University of Illinois to succeed J. W. Westwater, and C. W. Simmons at Lehigh to succeed H. A. Neville.

There were a few changes in the personnel of the Membership Committee because of elections in local sections and representatives moving out of the area covered by the local section they had been representing. They are as follows: P. J. Bonnell (Detroit), L. A. Webber (Texas Panhandle), J. R. McClain (Charleston), E. E. Litkenhous (Tennessee) and R. V. Heinze (Aruba).

Word has been received in the Secretary's Office that three A.I.Ch.E. members have joined the Armed Forces, namely, J. W. Kenney, R. Sanchez, and G. S. Baldwin, Jr. Their names were placed on the Suspense List to be exempt from dues' obligations for the period of their service.

At the request of the Anson Marston Medal Board of Award of Iowa State College, R. S. Casey was appointed Institute representative.

Following the meeting there was discussion on several matters of importance to the Institute such as plans for the future and Council meeting schedule.

The Council met at The Chemists' Club Oct. 12. The Minutes of the September Council meeting were received and approved as well as the Minutes of the Executive Committee meeting of Sept. 16.

R. D. Hoak, chairman of the Industrial Waste Disposal Committee, presented a report of the activities of his committee and its plans for the future. He stressed especially the importance of cooperation with this committee in keeping it advised of problems in waste disposal, and sources of papers which might be available for symposia to be presented at national meetings of the Institute.

Secretary reported that remittance had been received from the local committee handling the meeting of the Institute at Minneapolis in the amount of $154.40 which represented the surplus from this meeting. It was voted that this money be credited to the Institute Meetings Account.

Report of the Tellers Committee on the Nominating Ballot for officers and directors was presented to Council. On the basis of this report the Election Ballot will be prepared.

Council received notice of election to the Conference of Representatives of the Engineering Societies of Western Europe and the United States and it was voted to accept this election.

The main item of business for this meeting was the appointment of chairmen of the standing committees of the Institute. This was completed.

A special committee of Council, known as the Committee on Committees, was appointed to review committee reports for the year 1951 and report to Council the highlights of these reports and any recommendations made by the various chairmen. This committee consists of: W. I. Burt, chairman, I. L. Murray and H. D. Wilde.

CANDIDATES FOR MEMBERSHIP

(Continued from preceding page)

Robert L. Opila, *Argo, Ill.*
Stanley J. Pavilon, *Louisville, Ky.*
Sorrel Povlow, *Phila., Pa.*
John L. Priest, *College Park, Ga.*
M. Rabinovitch, *Beaver, Pa.*
J. Carter Reynolds, *Louisville, Ky.*
Donn F. Rice, *Akron, Ohio*
Alvin Wm. Ries, *Whiting, Ind.*
Ralph M. Robinson, *Chicago, Ill.*
John P. Sachs, *Chicago, Ill.*
Fred J. Sackfield, *Louisville, Ky.*
Edward W. Schnabel, *Kansas City, Mo.*
Kenneth A. Scott, *White Plains, N. Y.*
John Whitney Sicard, Jr., *Baton Rouge, La.*
Herbert Simon, *Phila., Pa.*
Noralf O. Swennes, *Louisville, Ky.*
Ward H. Swift, *Richland, Wash.*
Donald A. Waitzman, *Boston, Mass.*
Edward Richard Weber, *Kansas City, Mo.*
F. J. Wechter, *Oak Lawn, Ill.*
Robert R. Wiethaup, *Oak Ridge, Tenn.*
Paul E. Wilt, III, *Wilmington, Del.*
Edward L. Wolffe, *Washington, D. C.*
Eugene E. Woodward, *Oklahoma City, Okla.*
Louis Zinck, *Texas City, Tex.*

LOCAL SECTION

SOUTH TEXAS

Sixth Annual Technical Meeting

More than 500 chemical engineers, students and guests convened at the Hotel Galvez, Galveston, Tex., Oct. 19, 1951, for the Section's Sixth Annual Technical Meeting. A social hour and banquet with more than 300 of the registrants in attendance culminated the day's activities. The speaker at the banquet was Francis J. Curtis, assistant administrator for the National Production Authority in Washington and a former President of A.I.Ch.E. His address was entitled, "Washington Sidelights."

A high spot of the evening's program was the presentation of the Third Annual Award by this Section for the best technical paper published by a member of the Section in the preceding year. This year's award went to Kenneth A. Kobe of the University of Texas. Dr. Kobe's paper, coauthored by R. A. Troupe, was the result of a fundamental study in chemical reaction kinetics.

Technical Sessions

Following a welcoming address by Wayne E. Alexander, chairman of The South Texas Section, J. W. Schall of the Houdry Process Corp., Marcus Hook, Pa., presented data on the applications of the Houdriforming process for the production of aromatics and high octane gasoline. Mr. Schall's paper was coauthored by Messrs. H. Heinemann and D. H. Stevenson. A competitive process, Fluid Hydroforming, was described by H. G. McGrath of M. W. Kellogg Co., Jersey City, N. J. E. Wayne Lewis, of Humble Oil and Refining Co., described the results of experiments in batch fluidization of solid particles in liquids reported in a paper coauthored by Ernest W. Bowerman. The session was concluded by Fred W. Sullivan, Jr., consultant of Madison, N. J., who discussed recent developments in the field of petrochemicals.

A concurrent morning session was presided over by William P. Schambra of Dow Chemical Co., Freeport, Tex. R. N. Giles, Standard Oil Company (Ind.), Chicago, presented the first paper which discussed problems of refinery waste disposal and the elimination of water pollution. George F. Jenkins, Carbide and Carbon Chemicals Corp., South Charleston, W. Va., followed up with a description of some

(Continued on next page)

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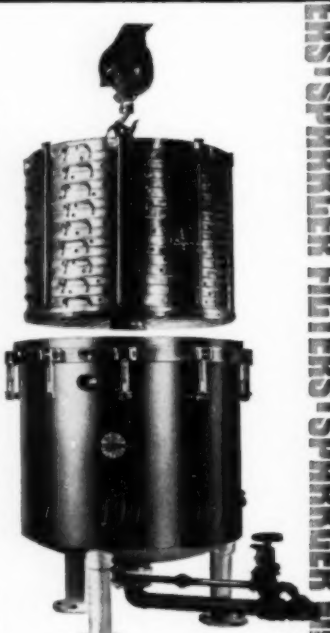

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SOUTH TEXAS

(Continued from preceding page)

specific problems in industrial waste elimination in a chemical plant, and how these problems were solved. Another aspect of industrial development, sources of fresh water for the Gulf Coast, was developed by Trigg Twitchell and W. L. Broadhurst of the U. S. Geological Survey, Austin, Tex.

At the afternoon general session Leroy B. Dampman, Carbide and Carbon Chemical Corp., Texas City, acted as moderator. "How to Make Heat Exchangers Behave" was the title of the first paper by Charles H. Gilmour, Carbide and Carbon Chemical Corp., South Charleston. W. W. Akers of The Rice Institute, Houston, described the use, applications and advantages of air-cooled heat exchangers for process and equipment cooling. Joseph Lichtenstein, Foster-Wheeler Corp., New York, presented a paper on the fundamental principles underlying a new code for cooling towers. The afternoon general session was concluded with a film by Humble Oil and Refining Co., Houston, describing an application of electronic computers for the rapid solution of problems requiring lengthy computation. The film was presented by Henry H. Rachford of Humble.

A second afternoon session was devoted to a series of papers intended to assist the young chemical engineer in making the transition from academic life to industry. What young chemical engineers can expect to get from the A.I.Ch.E. was defined by H. Dayton Wilde of Humble Oil and Refining. Presentation of both written and oral reports was discussed by Kenneth A. Kobe, The University of Texas. "Continuing Your Education After Graduation" was the subject of a paper by James R. Fair, Jr., Monsanto Chemical Co., Texas City.

The concluding paper by William C. Ford, psychological consultant, Houston, entitled "Psychological Attitudes of Young Engineers" covered several aspects of the personal development of a young engineer. The Student Session Moderator was Guy T. McBride, Jr., Dean, The Rice Institute, Houston.

Reported by N. H. McKay

WESTERN NEW YORK

This Section held its first meeting of the 1951-52 season Oct. 11 at the Iroquois Brewing Co., Buffalo, N. Y.

The meeting covered an inspection trip through the brewery which included the brewing and fermentation of the malt and the storage and bottling of the product.

Reported by W. C. Greenwald

EL DORADO

The first dinner meeting of the 1951-52 season was held at Dewey's Steak House in El Dorado, Ark., Sept. 21. The meeting was attended by 70 members and guests. M. R. Wingard, the guest speaker, presented an address on "Chemical Plant Engineering and Construction." Mr. Wingard is a sales engineer for the chemicals plants division of the Blaw-Knox Construction Co., Tulsa, Okla.

Mr. Wingard employed an electrolytic caustic-chlorine plant, which used the Mathieson Mercury Cell process as an example of the many problems that are encountered in chemical plant engineering and construction. Many problems, such as plant location, materials of construction, raw materials, process control and plant layout were discussed. Slides showing problems encountered in caustic-chlorine plants were shown.

Reported by R. L. Alexander

EAST TENNESSEE

The 29th general meeting was held Oct. 9 in the Recreation Building of the Tennessee Eastman Co., Kingsport, Tenn. Approximately 35 members and guests, including a number of men from the Organized Reserve Corps, heard C. E. Ford of the National Carbon Division, Union Carbide and Carbon Co. talk on "Karbate Process Equipment." Mr. Ford described cascade coolers and their development, concentric heat exchangers, and shell and tube exchangers. Slides were shown to illustrate the various types and their versatility. Pumps, piping, fittings and couplings made of Karbate were described as well as the proper installation methods for these materials.

Mr. Ford, who is chairman of the Local Sections Committee, reported on the work of that committee.

A motion picture, "Carbon, Black Treasure," was presented.

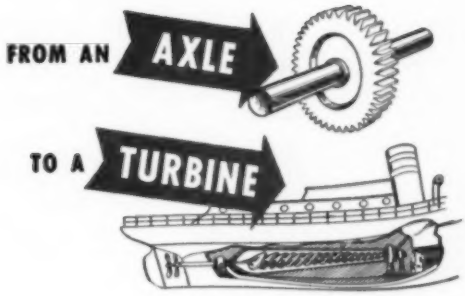
Reported by J. K. Pannill

SOUTHERN CALIFORNIA

This Section's monthly dinner meeting held Sept. 25 was attended by 111 members at the Rio Hondo Country Club. Clyde Berg, assistant to the vice-president of research, patents and development, Union Oil Company of California presented a talk on "Shale Oil, Our Most Promising Synthetic Fuel." Dr. Berg is active in the field of shale oil development and is chairman of the National Petroleum Council Subcommittee on Shale Oil Processing.

He reviewed the magnitude of the shale oil reserves of the United States which have been conservatively esti-

(*Continued on next page*)



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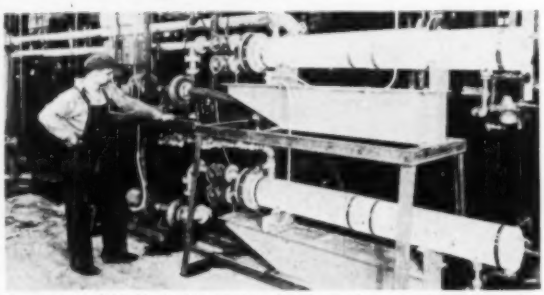

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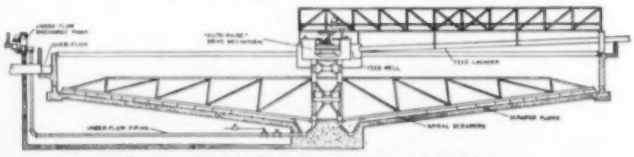

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SOUTHERN CALIFORNIA

(*Continued from page 75*)

mated at more than 300 billion barrels with more than 200 billion recoverable in Colorado alone. Dr. Berg presented diagrams and a discussion of the Union Oil retort which illustrated its advantages over previously developed retorting methods.

Reported by G. S. Peterson

OHIO VALLEY

This Section held its first meeting of the season Oct. 1 at the Engineering Society Headquarters in Cincinnati. Robert F. Romell, assistant manager of the engineering division of Vulcan Copper & Supply Co., was the principal speaker. Mr. Romell discussed the fabrication of chemical processing equipment and effect that fabricating methods can have on the basic design of chemical equipment. He also discussed the effect of materials of construction on design and methods of fabrication.

Reported by N. W. Morley

COLUMBIA VALLEY

The first fall meeting was held Sept. 27, 1951, at the Jefferson School cafeteria in conjunction with the Richland section of the American Chemical Society. The joint meeting was the result of a common interest in the topic of the speaker, N. H. Engle. The topic was "Resources Base for Industry in the Pacific Northwest."

Dr. Engle, director of the bureau of research, University of Washington, Seattle, Wash., is an economist, marketing specialist, teacher and author. His talk was replete with facts and figures on the various resources of the Pacific Northwest. After discussing the various economic factors involved in the economy of this region, Dr. Engle went on to picture the present economic status of the area in regard to the balance between them. A need for greater use of research, at least in the fields of economics, marketing and trade relationships, was stressed.

Reported by Carl F. Falk

NORTHERN CALIFORNIA

A meeting was held Oct. 15, in the Engineers' Club, San Francisco. A. B. Bakalar, associate director, patent division, Shell Development Co., discussed "The Corporate Patent Department."

The California Legislative Council of Professional Engineers is considering a proposal to amend the Registration Act to provide that chemical, electrical, mechanical, and petroleum engineers be registered in order to practice their profession.

PITTSBURGH

"Why is an Engineering Society" was the theme of an address by Thomas H. Chilton, 1951 President of A.I.Ch.E. at the opening dinner meeting of the 1951-52 season, held Oct. 3 at the College Club. Seventy-two members and guests were in attendance.

The speaker, who is technical director of the development engineering division, Du Pont Co., listed the two main objectives of any engineering society: advancement of the science of engineering, maintenance and enhancement of high professional standards. Evidence of A.I.Ch.E.'s continuing efforts in these directions was apparent, he said, in the current activities of A.I.Ch.E., such as (1) present and projected publications policy; (2) Institute awards and meetings; (3) Local section one-day symposia and programs; (4) various standing committees in the national organization, and, (5) recent changes in membership classifications and voting requirements.

Dr. Chilton went on to explain the work of A.I.Ch.E. in cooperation with joint organizations of national professional societies, such as E.C.P.D. (internal activities in the engineering profession) and E.J.C. (external activities).

Reported by Hugh L. Kellner

WESTERN MASSACHUSETTS

This Section held a dinner meeting at Blake's Restaurant in Springfield, Mass., on Sept. 20. A successful year ahead was indicated by a turnout of 55 members for this first meeting of the fall season.

A report on the Rochester meeting was presented by H. L. Minckler, chairman-elect of the Section.

Willis M. Cooper, newly appointed division engineer of Monsanto's organic division, who recently spent several years in England as chief engineer of Monsanto Chemical Limited, spoke on "The Chemical Industry in England."

A short technicolor film on the English Chemical Industries and a question-and-answer period concluded the program.

Reported by R. H. Merks

DETROIT

A meeting was held at the Engineering Society of Detroit, Oct. 3. R. H. Samis of Sharples Chemicals, Inc., discussed the subject "Practical Experience in the Production of Amyl Alcohol." The 50 members in attendance heard Mr. Samis relate the historical background of the development including many humorous incidents.

Reported by Dwight Miller

(*More Local Section on next page*)

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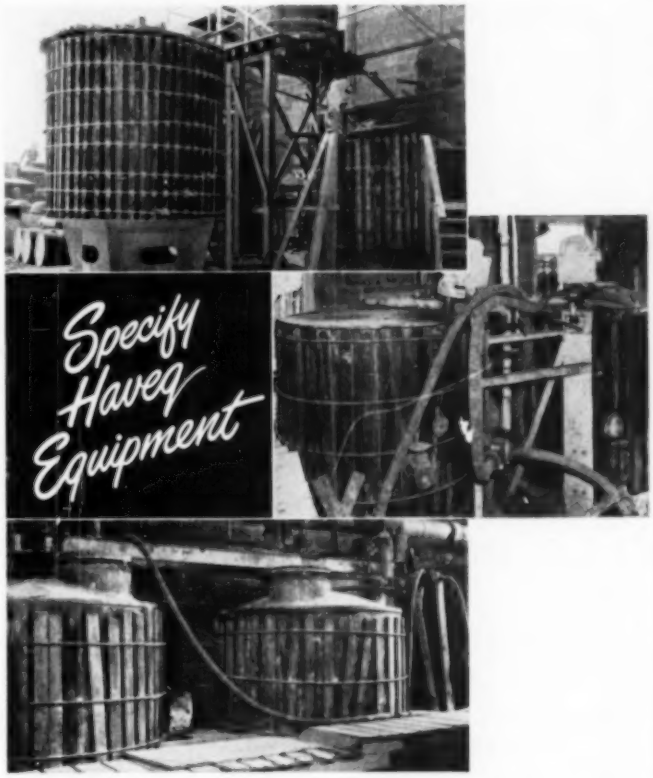

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(*Left*) Lawrence Heavy Duty Self-Priming Chemical Pump.

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LABOR LEADER AT NEW JERSEY

The biggest single need for smoother relations between management and labor is education in human relations, according to H. A. Bradley, president of the International Chemical Workers Union, A.F. of L., who spoke before the New Jersey Section of A.I.Ch.E., Oct. 9.

Bradley, who was invited by the chemical engineers to discuss the role of labor in the chemical field, also said that industry has fallen down on the job of educating management to understand labor. During his talks he traced the rise of friendly labor relations in the chemical field, and at one point, said that he does not know of a door today in the chemical field, that is not open to him or to his union, and that the managers in the chemical field are as fine a group of people as he has ever known.

Aside from those bouquets, Bradley talked mostly about the need for better understanding between labor and capital, saying they were partners, and for smoother operation they needed complete understanding of each other for a successful enterprise. He also mentioned the causes of major strikes in the past, listing five basic reasons as follows: The practice of hiring for minimum of wages and pitting one laborer against the other. This in effect bid down the cost of labor, made the men bitter and engendered the philosophy of getting even; the second practice which is not prevalent today as it was in the early 30's was nepotism, and making room for favorites in the plant; the depression practice of manual labor for college graduates, starting them at menial tasks and thereby displacing labor was given as a third cause; fourth, the depression itself, and fifth, ignoring labor unions and refusing to deal with them.

These causes are not as prevalent today he said, and out of the unionization activities there has come a great deal of good, he claimed, since management and labor were both put in direct contact with their mutual problems.

PHILADELPHIA-WILMINGTON

The first meeting of the 1951-52 season was held at Kugler's Restaurant, Philadelphia, Pa., Oct. 9, 1951. The dinner was attended by 106 persons, and approximately 120 people were present for the meeting that followed.

W. T. Dixon, chairman of the General Committee on Arrangements for the Atlantic City meeting, reported on the progress being made by the various individual committees.

Thomas H. Chilton, President of A.I.Ch.E., presented the award for the

best presentation of any paper at the White Sulphur Springs March meeting to James B. Jones, Jr., of the Du Pont Co., Inc. Mr. Jones presented the paper "Scale-Up of Semiworks Distillation Equipment" which he coauthored with Cyrus Pyle, also of Du Pont.

The speaker for the evening was Kermit Fischer of Fischer & Porter Co., Hatboro, Pa. His talk, titled "Not About Rotameters," dealt with personal experiences and conclusions drawn therefrom in the transition to management engineering.

Reported by W. E. Osborn

CHICAGO

Approximately 140 members and guests met at the Western Society of Engineers' suite Oct. 17 for a social hour and then dinner. The technical session featured R. N. Du Puis, research and development director for S. C. Johnson & Son, who spoke on "Wax Raw Materials and Formulated Products." His presentation covered the gathering and refining of vegetable waxes as well as research and development of new wax formulations. The novel research laboratory recently erected by his company was also described.

J. H. Rushton of Illinois Institute of Technology, was given the A.I.Ch.E. Citation for Outstanding Presentation of a Technical Paper at a recent section board meeting, for a paper he delivered at White Sulphur Springs. This citation was also given at the Oct. 17 section meeting to R. H. Elkins of the Sinclair Research Laboratories for his paper given at the Kansas City meeting.

Reported by Thorpe Dresser

NEW YORK

Jack Curran, union organizer and executive, will present the views of organizeil labor in the chemical industry at a luncheon meeting Nov. 29. The meeting will be held at the Brass Rail Restaurant, 745 Seventh Avenue, N. Y.

The speaker has been since 1948 a regional director and member of the International Executive Board of the United Gas, Coke and Chemical Workers of America (CIO).

Subjects to be covered by Mr. Curran are union objectives, methods of union operation, advantages of union membership, relations of unions with management, and professional chemical unions.

At the Sept. 25 meeting, Kenneth H. Klipstein, director of the chemical division of National Production Authority, spoke on the subject, "Washington and the Chemical Industry."

Reported by C. H. Chilton

Perhaps the most interesting feature of this Duraspun High Alloy Casting is that four different sizes of centrifugal castings are involved. These vary from 34" to 3½" in diameter. Sections, outlets, collar bands, lugs etc., were all welded together in our shop to form the retort as you see it in the picture. Assembled weight runs around 7,464 pounds.

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FUTURE MEETINGS AND SYMPOSIA OF A.I.Ch.E.

Chairman of the A.I.Ch.E. Program Committee

Walter E. Lobo, The M. W. Kellogg Co., 225 Broadway, New York 7, N. Y.

MEETINGS

Annual — Atlantic City, N. J., Chalfonte-Haddon Hall Hotel, Dec. 2-5, 1951.

Technical Program Chairman: Frank J. Smith, Pan American Petroleum & Transport Co., 122 East 42nd St., New York 17, N. Y.

Atlanta, Ga., Atlanta Biltmore Hotel, Mar. 16-19, 1952.

Technical Program Chairman: H. E. O'Connell, Ethyl Corp., Box 341, Baton Rouge, La.

French Lick, Ind., French Lick Springs Hotel, May 11-14, 1952.

Technical Program Chairman: W. W. Kraft, The Lummus Co., 385 Madison Avenue, New York, N. Y.

Chicago, Ill., Palmer House, Sept. 11-13, 1952.

Technical Program Chairman: D. A. Dahlstrom, Chem. Eng. Dept., Northwestern University, Evanston, Ill.

Annual — Cleveland, Ohio, Hotel Cleveland and Carter Hotel, Dec. 7-10, 1952.

Technical Program Chairman: R. L. Savage, Dept. of Chem. Eng., Case Inst. of Tech., Cleveland 6, Ohio.

Biloxi, Miss., Buena Vista Hotel, Mar. 8-11, 1953.

Toronto, Canada, Royal-York, April 26-29, 1953.

Annual—St. Louis, Mo., Hotel Jefferson, Dec. 13-16, 1953.

SYMPOSIA

Opportunities in Sales for Chemical Engineers

Chairman: F. J. Curtis, Monsanto Chem. Co., 75 Rust Bldg., 1001 15th St. N.W., Washington 5, D.C.

Meeting—Atlantic City, N. J.

Chemical Engineering Fundamentals

Chairman: W. C. Edmister, Chem. Eng. Dept., Carnegie Inst. of Tech., Pittsburgh 13, Pa.

Meeting—Atlantic City, N. J., and Atlanta, Ga.

Effective Speaking

Chairman: L. P. Scoville, Jefferson Chem. Co., 711 Fifth Ave., New York 22, N. Y.

Meeting—Atlantic City, N. J.

New Types of Equipment for Use in Process Industries

Chairman: D. M. Considine, Market Extension Div., Ind. Div., Minneapolis-Honeywell Regulator Co., 7th and Grange Sts., Philadelphia, Pa.

Meeting—Atlanta, Ga.

Market Research

Chairman: R. M. Lawrence, Monsanto Chem. Co., St. Louis 4, Mo.

Meeting—Atlanta, Ga.

Vacuum Engineering

Chairman: W. W. Kraft, The Lummus Co., 385 Madison Avenue, New York, N. Y.

Meeting—French Lick, Ind.

Filtration

Chairman: F. M. Tiller, Dir., Div. of Eng., Lamar State College of Technology, Beaumont, Tex.

Chemical Engineering in Hydrometallurgy

Chairman: John D. Sullivan, Battelle Memorial Institute, Columbus, Ohio.

Co-Chairman: John Clegg, Battelle Memorial Institute, Columbus, Ohio.

Fluid Mechanics

Chairman: R. W. Moulton, Head, Dept. of Chem. Eng., University of Washington, Seattle, Wash.

Authors wishing to present papers at a scheduled meeting of the A.I.Ch.E. should first query the Chairman of the A.I.Ch.E. Program Committee, Walter E. Lobo, with a carbon copy of the letter to the Technical Program Chairman of the meeting at which the author wishes to present the paper. Another carbon should go to the Editor, F. J. Van Antwerpen, 120 East 41st Street, New York 17, N. Y. If the paper is suitable for a symposium, a carbon of the letter should go to the Chairman of the Symposia, instead of the Chairman of the Technical Program, since symposia are not scheduled for any meeting until they are complete and approved by the national Program Committee. Before authors begin their manuscripts they should obtain from the meeting Chairman a copy of the Guide to Authors, and a copy of the Guide to Speakers. The first book covers the preparation of manuscripts, and the second covers the proper presentation of papers at A.I.Ch.E. meetings. Presentations of papers are judged at every meeting and an award is made to the speaker who delivers his paper in the best manner. Winners are announced in *Chemical Engineering Progress*, and a scroll is presented to the winning author at a meeting of his local section. Since five copies of the manuscript must be prepared, one should be sent to the Chairman of the symposium and one to the Technical Program Chairman of the meeting, or two to the Technical Program Chairman if no symposium is involved and the other three copies should be sent to the Editor's office. Manuscripts not received 70 days before a meeting cannot be considered.

PEOPLE

Harold Reintjes has been appointed special assistant to C. A. Stokes, director of the research and development department of Godfrey L. Cabot, Inc., Boston, Mass. He has also been named vice-president and general manager of Petrocarb Equipment, Inc., a New York engineering firm owned jointly by Godfrey L. Cabot, Inc., and three other firms. His office will be in New York. Mr. Reintjes has been engaged in research and development in an administrative and engineering capacity since his graduation from Rose Polytechnic Institute, Terre Haute, Ind., in 1935, where he received his B.S. degree in chemical engineering.

Arthur W. Johnston is now sales manager for the Niagara Filter Corp., Buffalo, N. Y. He was previously affiliated with the Bulfovak division of the Blaw-Knox Co., Buffalo, N. Y., as a sales engineer.

Thomas Baron was recently appointed assistant director of research for the Shell Development Co., Emeryville, Calif. Previous to this appointment, Dr. Baron had been assistant professor of chemical engineering at the University of Illinois, Urbana, Ill., where he received his Ph.D. in chemical engineering in 1948.

Walter T. Fairchild, previously with the Du Pont Co., Niagara Falls, N. Y., is now with the Vanadium Corp. of America, Niagara Falls, N. Y., in the capacity of metallurgist.

James E. Fitzgerald, assistant chief chemical engineer of the Brunswick-Balke-Collender Co., Muskegon, Mich., has been appointed head of the company's new laminated plastics division at Marion, Va. Much of the initial work of the division will be for military aircraft. Mr. Fitzgerald, who received his degree in chemical engineering from the University of Michigan, has been with Brunswick since 1940. For the past four years he has been employed primarily in research and development work and recently completed an intensive study of aircraft work on the West Coast.

(*More about People on page 82*)

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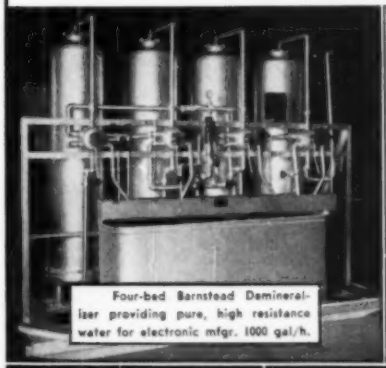

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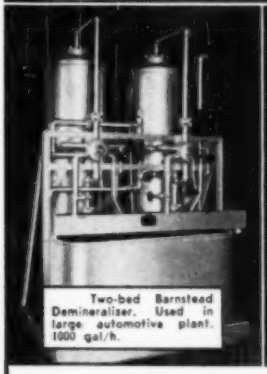

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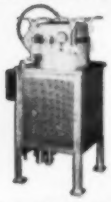

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PEOPLE

(Continued from page 81)

Jerome Alexander
Photo from painting (Vahan Sewny)

C. E. Starr, Jr.

J. E. Moise

C. E. Starr, Jr., was recently appointed manager of the newly established department of public relations of the Standard Oil Development Co., an affiliate of the Esso Standard Oil Co. Mr. Starr had been an assistant director of Esso Laboratories at Baton Rouge refinery of the Esso Standard Oil Co.—Louisiana division. J. E. Moise will succeed Mr. Starr as an assistant director at Baton Rouge.

Mr. Starr was graduated from M.I.T. as a B.S. in chemical engineering in 1931. During the period 1933-36 he was employed by Du Pont Co., and in the latter year became associated with Esso Laboratories of the Esso Standard Oil Co. as a chemical engineer at Baton Rouge. Subsequently he was made assistant director.

Mr. Moise was graduated from Tulane University in 1933 with a B.S. in chemical engineering. Late in 1933 he was employed as a chemical engineer at the Baton Rouge Esso Laboratories. He has been with the Laboratories' staff continuously since that time.

HONOR HARRY McCORMACK

As a tribute to Harry McCormack, professor emeritus of Illinois Institute of Technology, a Food Processing Fellowship for the advancement of the sciences in the industrial processing of foods was recently established by the Illinois Institute and the Putman Publishing Co., both of Chicago. This fellowship of $2,000 provides for one year of graduate study at the I.I.T. Professor McCormack was for 38 years director of the department of chemical engineering at I.I.T.

JEROME ALEXANDER RECEIVES NEW HONOR

With the placing on an oil painting of Jerome Alexander alongside the portraits of the most distinguished chemists of this country in the Maison de la Chimie in Paris, a new honor has been bestowed upon one of this country's leading scientists. The portrait, the work of Vahan Sewny, an outstanding portrait painter, will be presented to the Maison de la Chimie during the International Congress of Chemistry which will be held in France from Nov. 22 to Dec. 2 by the American Section of the Societe de Chimie Industrielle. It will be presented by Dr. Robert S. Aries, vice-president of the American Section of the Society.

The American Section of the Society will have its meeting Jan. 10, 1952, at the French Embassy Cultural Office, 934 Fifth Avenue, New York. Worth Wade, an executive of the American Viscose Co. and president of the Section will speak.

Dr. Alexander, one of this country's first chemical consultants and the editor of a series of books on "Colloid Chemistry," is founder of the American Section of Societe de Chimie Industrielle. Upon its reactivation early this year, he was designated Honorary Secretary of the Section.

Carl C. Monrad, professor and head of the department of chemical engineering at Carnegie Institute of Technology, Pittsburgh, Pa., will assume a new professorship in chemical engineering there through a newly established grant from Columbia-Southern Chemical Corp., a subsidiary of Pittsburgh Plate Glass Co. Dr. Monrad, who joined the Carnegie faculty as an associate professor of chemical engineering in 1937, became a full professor five years later and was made head of his department in 1947. At present he is a consultant to the office of Rubber Reserve of the Reconstruction Finance Corp., Washington, D. C. From 1930-37 he was a research chemical engineer and group leader for the Standard Oil Co. (Ind.) He was granted a leave of absence in 1940-41 to serve on the petroleum branch of the National Defense Advisory Commission. From 1944-47 and 1949-50 he was vice-chairman of the Pittsburgh Section, A.I.Ch.E., and chairman from 1950-51. The new grant will support research in chemical engineering.

PEOPLE

Anthony P. Massa is now associated with the H. K. Ferguson Co. as a chemical process engineer. He was formerly with the Stein-Hall Co. as a project and design engineer, following two years in the United States Army Signal Corps, in the last year of which he was in charge of the chemical testing department of the laboratory, planning and supervising all chemical testing on equipment. Mr. Massa obtained the degree of master of chemical engineering from the Polytechnic Institute of Brooklyn in June of this year. He is continuing part-time studies for his doctorate in chemical engineering at the Polytechnic.

Paul N. Cheremisinoff is now a research chemist for the Swan-Finch Oil Corp., West Englewood, N. J. Previous to this assignment he was a research engineer for Parsons Imports and Plymouth Organic Laboratories, Inc., Brooklyn, N. Y.

William F. Hoot is now a chemical engineer in the process development research division of the Pan American Refining Corp., Texas City, Tex. He was formerly a process design engineer for Ethyl Corp., Baton Rouge, La.

Donald A. Levenson is now sales promotion manager for American Chemical Society Publications of the Reinhold Publishing Corp., New York, N. Y. He was formerly a chemical engineer at the Hercules Powder Co., Parlin, N. J.

Richard L. Demmerle, formerly executive editor of Chemical Week, has been appointed assistant director of administration for General Aniline & Film Corp., New York, N. Y. Following his graduation from Columbia University, Mr. Demmerle was made administrative officer to the director of research at Manhattan Project Laboratories. From 1945-50 he was associate editor of Chemical Engineering News and Industrial and Engineering Chemistry and left these publications to join McGraw-Hill.

(*More about People on page* 85)

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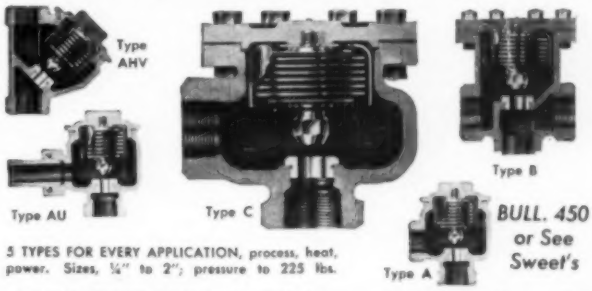

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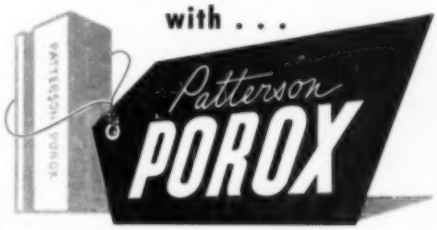

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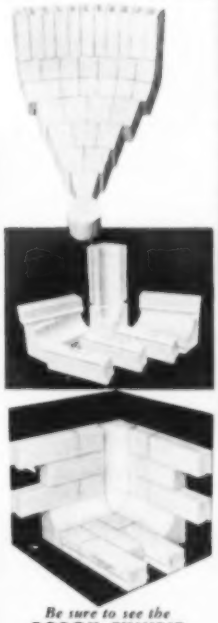

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(Continued)

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(People continued from page 83)

Harold L. Maxwell, supervisor of general consultants, Du Pont Co., Inc., Wilmington, Del., has been elected a vice-president of the American Society for Testing Materials. He will serve through the Society's 50th Anniversary Meeting in New York, June, 1952. Dr. Maxwell received his Ph.D. in chemical engineering and metallurgy in 1924 from Iowa State College; he was instructor in Industrial Chemistry there for two years, and associate professor of chemical engineering, Purdue University, 1926-1930. He has been affiliated with the Du Pont Co. since 1930 and was appointed to his present position as supervisor of general consultants in 1946.

Ralph W. Holbrook, formerly with the Colgate-Palmolive-Peet Co., Jeffersonville, Ind., is now affiliated with the Stone & Webster Engineering Corp., Boston, Mass.

Dwight R. Means is now vice-president of the Columbia-Southern Chemical Corp., Pittsburgh, Pa., a subsidiary of the Pittsburgh Plate Glass Co. He was formerly assistant to the vice-president of that company's Columbia chemical division.

Michael P. Mauzy, previously a graduate assistant in the chemical engineering department of the University of Tennessee, is now employed in the phosphate division of the Monsanto Chemical Co., Anniston, Ala.

James L. Vaughan has been appointed director of the process engineering department at National Research Corp., Cambridge, Mass. Mr. Vaughan received his B.S. in chemical engineering from the Massachusetts Institute of Technology in 1936 and his M.S. in 1937. From 1937-43 he was employed as a chemical engineer by Standard Oil Company (N. J.). Subsequently he worked for Shell Chemical Corp. as chief technologist at its Dominguez and Martinez plants. He left Shell to become assistant professor of chemical engineering at Rhode Island State College, Kingston, R. I. In 1947 he joined the staff of Rohm and Haas Co., Philadelphia, Pa., as a design and development engineer.

A. J. Abbott, formerly head of the chemical pilot plant of the Defence Research Board, Ottawa, Canada, is now with the Michigan Chemical Corp., St. Louis, Mich., as supervisor of the process and development department.

Lyle F. Albright, previously a chemical engineer for the Colgate-Palmolive-Peet Co., Wyckoff, N. J., is now an assistant professor of chemical engineering at the University of Oklahoma.

James M. Bonnell, formerly a teaching assistant in the chemical department of the University of Florida, is now a senior research engineer for the Snow Crop Co., Dunedin, Fla.

Seymour Brecher is now with the Colgate-Palmolive-Peet Co., Ridgefield, N. J., as a senior project engineer. He was formerly with the Pabst Brewing Co., Milwaukee, Wis., as a chemical engineer.

M. M. Chmilar is now a laboratory instructor in the department of petroleum and chemical engineering at the University of Alberta, Edmonton (Alta.), Canada. He had previously been with the Defence Research Chemical Laboratory at Ottawa, Canada.

William P. Cloyes, formerly development engineer in the titanium division of the National Lead Co., South Amboy, N. J., is now assistant to the plant manager of the Titanium Metals Corp. of America, Henderson, Nev.

Dallas E. Hawkins II is now chief engineer with Canadian Delhi Oil Ltd., Calgary (Alta.), Canada. He was formerly associated with the Comanche Corp., Dallas, Tex.

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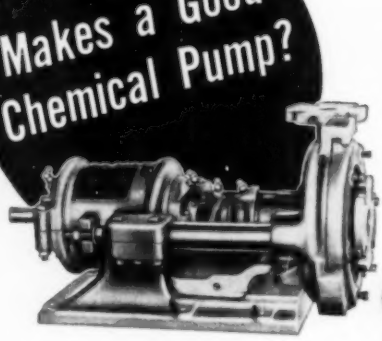

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PEOPLE

(Continued from page 85)

MACHWART FOR MONSANTO ON-THE-JOB EXPERIENCE

The first professor selected in the continuation of the program of Monsanto Chemical Co., which permits university and college faculty members in chemical engineering to gain a full year's on-the-job experience in chemical engineering, is George M. Machwart of Houghton, Mich., professor of chemical engineering at Michigan College of Mining and Technology. He has been assigned to the research department of Monsanto's phosphate division at Anniston, Ala.

Dr. Machwart, a native of Savannah, Ohio, received an M.S. degree in chemistry from Wooster College (1926) and his Ph.D. degree in chemical engineering from Ohio State University (1930). From 1930 until 1942 he was assistant professor of chemical engineering at the University of Maryland. He joined the department of chemical engineering at Michigan College in 1942.

Antonio Caldarelli is now a graduate engineer student at Columbia University, New York. He was formerly a junior project and development engineer for the Pennsylvania Salt Manufacturing Co., Easton, Pa., and received his B.S. in chemical engineering from City College, New York.

Walter J. Armstrong is now an engineer for the International Bank for Reconstruction and Development, Washington, D. C. He was formerly with the Banco Nacional de Nicaragua, Managua, Nicaragua.

Necrology

FRANK H. MERRILL

Frank H. Merrill, past president of the Los Angeles (Calif.) Soap Co., died Oct. 12. Early in his career he was associated with Jobbins & Van Ruynbeke, Aurora, Ill., working on design, erection and operation of plants for the recovery of glycerine from waste soap lye and sweet waters from candle factories, and the refining of this glycerine. In 1897 he accepted a position with the Los Angeles Soap Co. as superintendent in charge of manufacturing and subsequently was in charge of manufacturing and all plant operations and additions and improvements. Later he was elected president. Mr. Merrill received his technical education at the Massachusetts Institute of Technology and was awarded a B.S. in chemical engineering. He was a charter member of A.I.Ch.E.

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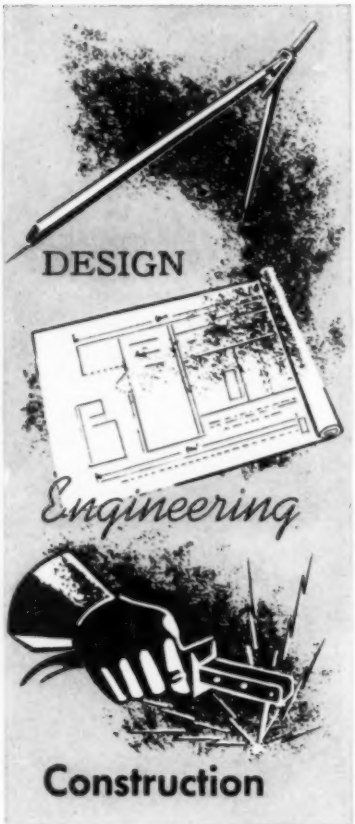

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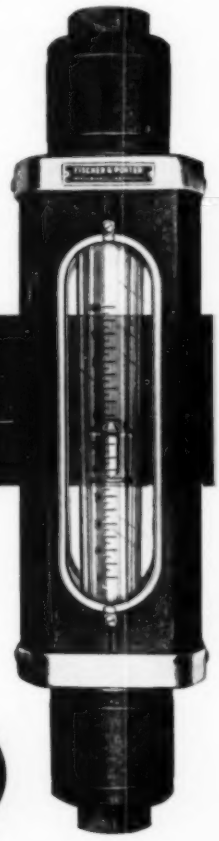
FACTOR TAGS Each meter as supplied has a factor tag applicable to the service requirement at the time of purchase. A change in service requires only a change of tag, listing new data and factor.

COMPLETE DATA AVAILABLE Thousands of hours of experimentation and research in the F&P Hydraulic Laboratories have developed complete calibration data, available in handbook form.



FOUR BASIC PREDICTABLE FLOATS MEET MOST REQUIREMENTS

* The "float" is a basic metering element and the only moving part in the FLOWRATOR variable-area flow meter.

WRITE FOR HANDBOOK The F&P Variable-Area Handbook contains a complete compilation of float lists, prediction curves, float data and selection instructions, how to use curves and change meter capacities and much other information of value to all meter users. Your copy is free for the asking.

PROCESS CONTROL INSTRUMENTS

FLOWRATOR

FISCHER & PORTER COMPANY

HATBORO, PENNSYLVANIA, U.S.A.

SALES ENGINEERING OFFICES THROUGHOUT THE WORLD